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PROCEEDINGS

—OF THE—

Engineers' Society of Western Pennsylvania

PITTSBURGH, PA.

Volume XXI.

1905.

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SAMUEL DIESCHER.

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Treasurer, A. E. FROST, Secretary, F. V. McMULLIN.

Directors.
J. K. LYONS, MORRIS KNOWLES,
WILLIS WHITED, GEORGE T. BARNSLEY.

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D. W. McNAUGHER, CLIFFORD B. CONNELLY,
WM. A. BOLE.

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ARNOLD STUCKI, Chairman.
F. Z. SCHELLENBERG, J. L. KLINDWORTH, F. W. WINTER.

House Committee.
FRED C. SCHATZ, Chairman.
DANIEL ASHWORTH, WM. E. FOHL.

Library Committee.
THOS. H. JOHNSON, Chairman.
JOS. A. SHINN, H. C. BABBITT, PAUL L. HAY.

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Committee on New By-Laws.
WILLIS WHITED, Chairman.
CHARLES F. SCOTT. KARL F. STAHL.
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George P. Maury, Chairman.
Lawrence L. Arnold, Vice-Chairman, Harrison W. Craver, Secretary.

Directors.
Harry E. Walters, James M. Camp.
Programme: James M. Cramp, Chairman. C. H. Rich, R. L. Frink.
Chemical Literature: J. A. Mohr, Chairman. G. O. Loeffler, Philo Kemery.
N. H. Finley. W. E. Dickson.
Methods: A. G. McKenna, Chairman. H. E. Walters. J. O. Handy.

MECHANICAL SECTION.

H. H. Anderson, Chairman, W. H. Baltzell, Vice-Chairman, H. D. James, Secretary.

Directors.
L. C. Moore, J. L. Klindworth.

Programme Committee.
Edwin Fitts, Chairman.
W. C. Hawley, G. M. Campbell,
E. J. Dittmar, H. R. Kommer.

Reception Committee.
C. Ludlow Livingstone, Chairman.
M. C. Blest, C. H. Gisin,
C. R. Branson, F. D. Purdy.

STRUCTURAL SECTION.

E. K. Morse, Chairman.
R. A. Cummings, Vice-Chairman. T. J. Wilkerson, Secretary.

Directors.
T. D. Lynch, Francis S. Rice.

Engineers' Society of Western Pennsylvania.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS

The 25th annual meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's house, 410 Penn Avenue, Pittsburg, Pa., Thursday evening, January 5, 1905, at 8:25 P. M., President J. M. Camp in the chair and one hundred and thirty-one members and visitors present.

The minutes of the last, or twenty-fourth, Annual Meeting were read and approved.

The report of the Board of Direction was read by the Secretary as follows:

We recommend that the following persons be dropped from the rolls of the Society. They being three years in arrears for their dues: George McCully Laughlin, Jr., Thomas R. Brown, H. W. Armstrong, R. L. Todd, W. R. Marden, James S. Haring.

After several inquiries from certain members as to whether or not the parties who were back in their dues had received proper notices and been given every opportunity of canceling their indebtedness, all of which were answered in the affirmative by the Secretary, it was moved, seconded and carried that the recommendation of the Board be approved.

REPORT OF THE TREASURER.

Mr. President and gentlemen of the Society, it gives me great pleasure to present herewith a summary of the receipts and expenditures of our Society for the past year; this being my twenty-fourth successive annual report.

1904.
Jan. 1, Balance.....$3,796.97

Receipts.

Dues To Jan., 1902, @	$7.00	1	7.00	
" " 1903, "	5.00	1	5.00	
" " " "	7.00	8	56.00	
" " 1904, "	5.00	7	35.00	
" " " "	8.00	21	168.00	
" " " "	2.00 (¼ yr.)	6	12.00	
" " 1905, "	5.00	132	660.00	
" " " "	3.75 (¾ yr.)	6	22.50	
" " " "	2.50 (½ yr.)	1	2.50	
" " " "	1.25 (¼ yr.)	3	3.75	
" " " "	8.00	562	4,496.00	
" " " "	6.00 (¾ yr.)	16	96.00	
" " " "	4.00 (½ yr.)	2	8.00	
" " " "	2.00 (¼ yr.)	26	52.00	
" " 1906, "	8.00	7	56.00	
" " " "	5.00	5	25.00	
On account			2.50	
Initiation Fees		111	555.00	
Sale of Proceedings			222.88	
Rent			717.00	
Sundries			33.50	
				$11,032.60

Expenditures.

Transferred to Savings Account	$3,500.00	
Printing	1,854.49	
Office Expenses	549.42	
Telephone	67.00	
Stenographer	20.00	
Heat and Light	261.73	
Salary of Secretary	1,000.00	
Rent	1,560.00	
Water Tax	39.00	
Periodicals	15.85	
Repairs and Improvements	77.55	
Lecture Expenses	37.15	
Insurance	86.06	
Subscription, Society Chemical Industry	25.00	
Refund of overpayment	3.00	
Total		$ 9,096.25
Balance		1,936.35
		$11,032.60

Balance in Savings Accounts, including Building Fund.....$4,919.91

Respectfully submitted,

A. E. Frost.

Treasurer.

REPORT OF THE AUDITING COMMITTEE.

Mr. President—When the Auditing Committee finished their work last night I felt like occupying one of the pages of this book with a little memorial of Mr. Frost for his long term of service, this being the twenty-fifth anniversary of the Society, but the By-Laws do not call for that, so I simply said:

We, the undersigned, have examined the above accounts and find them to be correct.

Geo. T. Barnsley,
Morris Knowles.

REPORT OF SECRETARY.

Members at close of year ending January 7, 1904.....			888
At the annual meeting January 7, 1904, there were sixteen (16) names dropped from the roll.....	16		
There were forty-eight (48) resignations and ten (10) deaths during the year.....	58		
A total loss of.....		74	
During the year nine (9) of the applicants elected in 1903 matriculated.....	9		
During the year one hundred and eleven (111) applicants were elected members, and of these one hundred and four (104) matriculated.....	104		
A total gain of.....		113	
Making a net gain of.....			39
Total membership, January 5, 1905.....			927

The average attendance at the regular meetings of the society during the year was eighty-nine (89).

Approximate amount of dues and initiation fees unpaid and owing to the society, $1,894.00—10 members 3 years; 43 members 2 years; 122 members 1 year.

Chas. W. Ridinger,
Secretary.

Pittsburg, Pa., January 5, 1905.

Mr. James M. Camp,
President Engineers' Society of Western Pa.,
Pittsburg, Pa.

Dear Sir: Your Program Committee reports considerable trouble was experienced in procuring papers for the regular meet-

ings of the society during the past year. Specially prepared papers were provided for all the regular meetings, with but one exception. But one paper was prepared for each regular meeting, with the idea that it would encourage fuller discussion on account of providing ample opportunity for the members to discuss the paper.

It may be that the trouble experienced in procuring papers for the regular meetings of the society is due, in some measure, to the sections encouraging papers. We do not think that the preparation of papers by the sections should be encouraged, nor was this intended when authority was granted by the parent society for their organization. This feature is mentioned at this time, in order to bring it before the society at its annual meeting, so that they may take action on the subject, should they deem it prudent to do so.

The tendency to publish advance papers without the sanction of the Program Committee does not seem desirable. Because the society has been prosperous the last few years, in so far as its finances are concerned, we do not think it is justification for expenses being increased unnecessarily in the matter of its publications.

Respectfully submitted,

JAMES K. LYONS,
Chairman Program Committee.

PITTSBURG, PA., January 5, 1905.

MR. JAMES M. CAMP,
President Engineers' Society of Western Pa.,
Pittsburg, Pa.

Dear Sir: On behalf of the Reception Committee for the year 1904, I have to say, it has been the pleasure of your committee to do the greatest amount of good to the largest number. Pittsburg is a prolific section of country to the technical man. Much is going on and sometimes the member is so engrossed with his own particular work as to forget the work of others. With the idea, "there are others," the following excursions of inspection were arranged for in and about Pittsburg:

January 30, Pennsylvania R. R. Power Plant, Union Station, Pittsburg.

March 12, Farmers' Bank Building, Pittsburg.

March 23, Frank-Kneeland Machine Company Plant, Pittsburg.

April 30, Pennsylvania Lines, Fort Wayne Bridge and Elevated Tracks, Allegheny.

May 18, The American Automatic Voting Machine, Home Trust Building, Pittsburg.

October 24, Bessemer Building, Phipps Power Building and Gayety Theatre, Pittsburg.

November 5, Mesta Machine Company's Plant, West Homestead.

November 12, New Lock No. 2, Monongahela River.

November 19, Reinforced Concrete Factory Building for Taylor, Wilson & Co. and the Pittsburg & Lake Erie R. R. Shops at McKees Rocks.

December 3, The Fayette Coal Company's Chalfant Mine at Noblestown.

These excursions were participated in by from forty to two hundred members. There has been much interest taken in these gatherings, which bring the members together in close, personal contact. Informal luncheons of the most hospitable character have been tendered, the most notable being by the Pressed Steel Car Company, The Frank-Kneeland Machine Company, The Mesta Machine Company, and the Dravo Contracting Company. The Pittsburg and Lake Erie R. R. Company and the Fayette Coal Company furnished complimentary transportation.

Your committee regrets that the society's house was not suited for social functions. A more commodious home with club features would do much to promote a closer fellowship.

The crowning feature of the year's work will be the Twenty-Fifth Annual Banquet, January 28, 1905, and we ask the co-operation of every member to make it a signal success.

Yours very truly,

GEORGE T. BARNSLEY,
Chairman Reception Committee.

PITTSBURG, PA., January 5, 1905.

MR. JAMES M. CAMP,
President.

Dear Sir: In reply to your request for report from the House Committee for the past year, we beg to say that we have done nothing of any special note other than the routine work that has been regularly assigned to this committee.

Respectfully submitted,

FRED. C. SCHATZ,
Chairman House Committee.

PITTSBURG, PA., January 5, 1905.

MR. JAMES M. CAMP,
President Engineers' Society Western Pa.,
Pittsburg, Pa.

Dear Sir: Replying to a recent request sent out by the secretary for a report on the work done by the Library Committee during the past year, please note the following:

Practically no additions have been made to the library during the past year aside from the accumulation of current literature. The committee have made no efforts to add to it, on account of the fact that our library as at present has overgrown its quarters and has had to be stored in a room in the basement of this building. The size of the present rooms of the society prevent the fitting up of a library that would be a credit to such a membership, and so your committee have deemed it best to leave the books stored as at present.

A recent inspection of the books in their present quarters shows them to be in fairly good condition, probably as good as could be gotten outside of a regular library building with constant attendance. The room in which they are now stored is dry, and while the rats have caused considerable destruction to bundles of magazines stored loosely in open shelves, there is no evidence of injury to the bound volumes in the cases.

Some definite policy should be started as to what disposition should be made of the bundles of current literature that are rapidly accumulating. If certain periodicals are to be preserved, they should be bound yearly and not be tied up in bundles inaccessible

and readily damaged. Such matter as will not be bound should be destroyed at frequent intervals, as the present practice of storing everything is cumbersome and increases very materially the fire risk on the building.

Your committee recommend, therefore, that the succeeding Library Committee be instructed to have bound such periodicals as in their opinion are worth preserving. They further recommend a continuance of the present plan of storing the library; this seems to be a necessity in our present quarters.

Respectfully submitted,

S. M. KINTNER,
Chairman.

It was moved, seconded and carried, that a vote of thanks be extended to the various committees for their efficient work during the past year, with particular reference to the Reception Committee.

MR. SHINN—Preceding the election, I would like to offer a resolution as follows:

Whereas, Insomuch as the Constitution of the Society provides that a majority of the votes cast shall determine the election of its officers; and,

Whereas, It appears that there are three candidates for the office of secretary at this time. Now, therefore, be it

Resolved, That in the event of failure to elect a secretary on the first ballot, a second ballot shall be taken, and if not then decided a third ballot shall be taken; ballots on said third ballot being confined to the two candidates receiving the highest votes on the second ballot.

Motion seconded and carried.

It was moved, seconded and carried that the President appoint the usual number of tellers and proceed with the election for the ensuing year.

PRESIDENT—I will appoint on that committee Messrs. W. H. Smith, Daniel Ashworth, and Dr. Karl F. Stahl, who will please distribute the ballots to the members and collect same, retiring to the adjoining room to do the counting.

The President then directed the attention of the Society to the new photograph of Ex-President C. B. Albree, which had just been presented to the Society, in pursuance of the usual custom.

The tellers here announced the result of the first ballot, as follows:

Mr. Diescher for President, Mr. Kintner for Vice President, Messrs. Barnsley and Knowles for Directors, and Mr. Frost for Treasurer, 126 each; for Secretary, Mr. Craver, 31; Mr. Engstrom, 48; Mr. McMullin, 48.

As neither candidate for Secretary had received a majority of the votes, the ballots were again distributed, and the tellers announced the result, as to the Secretaryship only, as follows:

Mr. Craver, 28; Mr. Engstrom, 48; Mr. McMullin, 51.

In accordance with the resolution adopted prior to the commencement of the election, the name of Mr. Craver was dropped from the list, and a third ballot taken on the other two candidates, which resulted as follows:

Mr. Engstrom, 48; Mr. McMullin, 77.

The following officers were therefore declared elected for the year 1905:

PRESIDENT—Samuel Diescher.

Vice President—S. M. Kintner.

Directors—George T. Barnsley, Morris Knowles.

Treasurer—A. E. Frost.

Secretary—F. V. McMullin.

After the retiring President had read his address the meeting adjourned at 10 P. M.

The 251st regular meeting of the Engineers' Society of Western Pennsylvania was called to order at 8:15 P. M. Tuesday, January 17th, 1905, in the lecture room of the Society's House, with President Samuel Diescher in the chair, 64 members and visitors present.

The minutes of the last meeting were read by the Secretary and approved.

The report of the Board of Direction was read by the Secretary and the following candidates were recommended for membership.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
WILLIAM P. GLEASON,	Ass't Gen'l Supt. - Clairton Steel Co., Mitchell Ave., Clairton, Pa.	Chas. H. Rich, Geo. L. Collard, John G. Lanning.
EDWIN VAN D. JOHNSTON,	With Carnegie Technical Schools, 425 N. Negley Ave., Pittsburg, Pa.	A. A. Hammershlag, C. B. Connelley, Geo. T. Barnsley.
GEO. L. MILLER,	Gen'l Manager Kettle Creek Coal Mining Co. Bitumen, Penn'a.	Samuel Diescher, Alfred J. Diescher, F. V. McMullin.
GEO. W. PHILLIPS,	- Draftsman, - With Heyl & Patterson. 202 N. Dithridge St., Pittsburg, Pa.	D. C. Ashworth, J. P. Maxwell, Geo. T. Barnsley.
EDWIN E. RUSHTON,	Mechanical Draftsman. 419 Rebecca Ave., Wilkinsburg, Pa.	F. V. McMullin, Geo. T. Barnsley, Samuel Diescher.
ALEX. W. SLOCUM,	Supt. of National Car Wheel Co. 5500 Irwin Ave., Pittsburg, Pa.	Chas. V. Slocum, J. W. Hussey, L. B. Whitney.
BERNARD LESTER,	- Ass't Manager - Westinghouse Elect. & Mfg. Co., 403 Pitt St., Wilkinsburg, Pa.	J. L. Klindworth, A. L. Hoerr, G. K. Newbury.
FRED R. SITES,	- - Chief Draftsman. - Riter & Conley Mfg. Co. Box 128, Wilkinsburg, Pa.	A. Z. Newlin, W. A. Weldin, D. Turpit.
H. J. McKINLY,	County Surveyor of Venango Co. Rural Delivery 61, Harrisville, Pa.	E. K. Morse, Arthur Barnes, Harry J. Lewis.
EMERY CURRAN READ,	Land Surveying - 34 16th St., Franklin, Pa.	E. K. Morse, Samuel Diescher, A. E. Myers.

On motion the Secretary was ordered to cast the ballot electing the above applicants to membership.

The following resignations were reported as accepted by the Board: E. E. Arnold, H. C. Baker, J. C. Bole, A. L. Canavan, Presley J. Fickinger, H. C. Gould, Franklin Goheen, C. G. Hussey, Jos. R. Hague, J. A. Hunter, Thos. D. Gillespie, Henry

T. Irwin, F. E. House, H. E. Myers, W. D. Stevenson, A. D. Wilkins, C. F. Walthers and J. W. Marsh.

In reference to the recommendation of the Board of Direction that a reconsideration be had of the action of the Society three months ago requesting the Carnegie Institute in Washington, D. C., to give a hearing to Mr. H. W. Pearson, the motion to reconsider, having been duly made and seconded, after full discussion thereof, was put to vote and lost, there being but one vote cast in favor of such reconsideration. Whereupon, the President instructed the present Secretary to carry out the direction of the Society and forward the resolution.

The Secretary then read the names of the members of the Standing Committees for 1905.

Reception Committee—Geo. T. Barnsley, Chairman, Dr. Walther Riddle, D. W. McNaugher, Geo. H. Neilson, Ralph Crooker, Jr., and Alex. M. Gow.

Program Committee—Arnold Stucki, Chairman, F. Z. Schellenberg and F. W. Winter.

House Committee—Fred C. Schatz, Chairman, Daniel Ashworth and William Fohl.

Library Committee—Thos. H. Johnson, Chairman, Jos. A. Shinn, Paul L. Hay and H. C. Babbitt.

Mr. Stucki—I wish to take advantage of this occasion to thank you for the confidence you have placed in me. I trust we will have no trouble in getting the proper papers, and hope that every member in the Society will help us in this. If any one has a desire to hear a paper on any particular subject, or would be in position to read one himself, we would be very glad to know it.

I also want it distinctly understood, that we do not wish to handicap any of the Sections in selecting their papers or in their work, for if you do that, in my opinion you might just as well have no Sections at all.

In regard to editing or publishing the papers, however, I am of the opinion, that the papers to be printed should be carefully selected and the discussions should be condensed in order to be of any use. An engineer is a busy man and he should not be

called upon to read lengthy discussions if a few lines could be made to convey the same substance.

PRESIDENT—The next thing in order is the paper. I will call upon Ex-president C. B. Albree to take the chair.

After the reading and discussion of the paper the meeting adjourned at 10:30 P. M.

The regular monthly meeting of the Board of Direction was held at the Society's House, 410 Penn Ave., Pittsburg, Pa., Saturday evening, January 14th, 1905, at 8:00 o'clock.

Present, Messrs. Diescher, Kintner, Lyons, Whited, Barnsley, Knowles, Schatz, Stucki, Anderson, Engstrom, Ex-president Camp, and Secretary.

The minutes of the preceding meeting were read and approved.

A communication from Mr. Clifford Richardson with reference to securing the aid of the Bureau of Standards at Washington to bring about standard methods of chemical analysis of the country, was referred to the Chemical Section with the request to formulate a plan and report same to the Board of Direction.

An invitation was received from the President of the Railway Club of Pittsburg, to the officers of the Society to hold an informal conference relative to new quarters. On motion accepted.

Communication received from Mr. H. W. Pearson inquiring as to whether the Society had forwarded the letter to the Carnegie Institute, Washington, in accordance with the resolution passed at the October meeting of the Society, was on motion referred to the Society with the recommendation that it is unwise to establish a precedent by any such resolution of recommendation and that the motion passed be reconsidered.

On motion Secretary was directed to have a new membership list printed about Feb. 1st.

On motion Secretary was directed to have vouchers printed for payment of bills for the Society in the future.

On motion adjourned at 9:30 P. M.

F. V. McMULLIN,
Secretary.

CHEMICAL SECTION—ANNUAL MEETING.

The thirteenth annual meeting of the Chemical Section of the Engineers' Society of Western Pennsylvania was held the evening of January 19, 1905, in the Society House, 410 Penn avenue, Pittsburgh.

The meeting was called to order at 8:15 P. M., the chairman, Mr. H. E. Walters, presiding. Seventeen members and visitors were present.

In the absence of the secretary, the chair appointed Mr. H. W. Craver secretary *pro tem.*

For the Board of Direction Mr. Rich reported that there had been an increased interest in the work of the section during the year and that the outlook for the ensuing year was favorable.

No other reports were presented.

The chairman stated that owing to illness he had been unable to complete his address.

The Section then proceeded to the election of officers for the ensuing year. The following list of nominations was read by the secretary:

Chairman, George P. Maury; vice-chairman, Lawrence L. Arnold; secretary, Harrison W. Craver; directors, Harry E. Walters and James M. Camp.

No other nominations being made, Mr. McKenna moved that the secretary be instructed to cast a ballot electing these officers. Motion carried.

No other business coming before the meeting, on motion it adjourned.

HARRISON W. CRAVER,
Secretary pro tem.

JANUARY MEETING.

The regular monthly meeting of the Chemical Section of the Engineers' Society of Western Pennsylvania was held in the Society House, 410 Penn avenue, Pittsburgh, January 19, 1905, immediately upon the adjournment of the annual meeting.

The chairman and vice-chairman being absent, Mr. H. E. Walters was elected chairman *pro tem.*

The minutes of the December meeting were read and approved.

The secretary read a communication from the committee on uniformity in technical analysis of the American Chemical Society, asking aid in securing the co-operation of the National Bureau of Standards in their work, which had been referred to the section by the Board of Direction of the Society, with instructions to report to the Board. After discussion it was moved by Mr. McKenna that the chairman appoint a committee to investigate and report at the February meeting. Motion carried.

General discussion followed. Mr. McKenna spoke of some points observed in English technical laboratories. Mr. Babbitt mentioned some new electric-furnace products. Plans for the year's work were discussed.

At 9:30 P. M. the Section on motion adjourned.

HARRISON W. CRAVER,
Secretary.

MECHANICAL SECTION.

The annual meeting was held January 3, 1905. Meeting called to order at 8.25 o'clock, Chairman J. L. Klindworth in the chair. Twenty-six members and visitors present. Secretary's annual report read and approved. Report of Program Committee read by Mr. Stucki and approved. Nominating Committee reported the following nominations:

Chairman, H. H. Anderson; Vice Chairman, W. H. Baltzell; Directors, L. C. Moore, J. L. Klindworth; Secretary, H. D. James.

On motion the secretary was instructed to cast a ballot electing the officers as nominated. Mr. Anderson then assumed the chair, and Mr. Samuel Diescher read a paper on Bending Stresses in Wire Rope. Paper discussed by Messrs. Albree, Stucki, Klindworth, Lindstrom, Flanagan, Moore, Campbell and Anderson.

Mr. L. C. Moore then read a paper on Use and Abuse of Wire Rope. Discussed by Messrs. Babbitt, Flanagan, Jackman, Newbury, Hallsworth, Diescher and Klindworth.

Meeting adjourned 10:30 P. M.

H. D. James,
Secretary.

STRUCTURAL SECTION.

Annual meeting of the Structural Section of the Engineers' Society of Western Pennsylvania, was held in the Society Hall, at 410 Penn Ave., Tuesday evening, January 24, 1905.

Meeting called to order by Chairman Engstrom at 8:15 P. M.

As Secretary Whited was absent, Mr. T. J. Wilkerson was appointed temporary Secretary.

Minutes of last annual meeting read and approved.

The retiring Chairman, Mr. Frans Engstrom, then made his address. After the address the following officers were elected: Chairman, E. K. Morse; Vice Chairman, Robert A. Cummings; Secretary, Thomas J. Wilkerson; Directors, T. D. Lynch, Chas. Worthington.

Mr. C. L. Livingston was appointed as a committee of one to escort Mr. Morse to the chair. There being no further business before the annual meeting on motion the annual meeting adjourned.

T. J. Wilkerson,
Secretary S. S.

Regular meeting of Structural Section called to order. Minutes of last regular meeting read and approved.

Mr. Frank Rice then opened the discussion on Methods of Expansion in Railroad Bridges, and was followed by Messrs. Whited, Danforth, Morse and Wilkerson.

Mr. E. K. Morse then read a paper on Cushioned Road beds for Railroad Bridges. The same was discussed by Messrs. Rice, Lynch, and Wilkerson.

On motion a vote of thanks was tendered Messrs. Rice and Morse.

On motion Section adjourned at 10:00 P. M.

T. J. Wilkerson,
Secretary S. S.

RECENT EXAMPLES OF APPLIED CHEMISTRY.*

BY JAMES M. CAMP,
Member Engineers' Society of Western Pennsylvania.

Like all bodies uninfluenced by forces outside of itself, the engineer also will take the path of least resistance and, therefore, if he must write at all, he will choose that subject with which, if he is not familiar with, he has at least a speaking acquaintance. Although educated as an engineer, my profession is that of a chemist and I have naturally selected a subject along that line, as the one I am best acquainted with, and I propose to mention a few of the applied chemical problems of to-day that were comparatively the purely scientific problems of yesterday.

The subject is a worthy one when one considers that the value of the products annually produced is over one hundred million dollars, and that this includes purely the chemical products, some of which I am about to describe.

How far reaching it is can be imagined when it is known that a person reading continuously could not keep pace with the literature of the subject. There is hardly an industry of the day that the various steps in the processes are not safeguarded by the chemist. They are the sentinels standing at the doors of all modern factories and mills, saying unto all things that enter into the manifold processes, "Who art thou?" and unto all the finished materials leaving, "What art thou?" and until those two questions are answered to the satisfaction of the chemist, there is no entering, no leaving. Their vigilance safeguards us in all things from the proof of the purity of our baby food on through childhood, youth, manhood and old age, to the final proof of the thinness of the plating on the solid silver handles of our casket.

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*Address of the Retiring President at the twenty-fifth Annual Meeting of the Engineers' Society of Western Pennsylvania, Jan. 5, 1905.

And the chemist of the day is no longer a theorist searching idly for the unknown or the impossible but a combination of this and the practical and with a well defined idea of what is most wanted to help the world onward on the road to progress.

Over a subject so vast, the writer necessarily must skim but lightly, touching but here and there to maintain the interest of the paper to those of my audience, the majority of whom are not chemists, while the whole story, when told, reads like a fairy tale.

Synthetic electrochemistry, by which is meant the electrical production of chemical substances, has provd an important factor in the world of trade. Many articles, which a few years ago found use only within very narrow limits on account of the expense, are to-day manufactured on a large commercial scale and at a wonderfully reduced cost.

Electrochemistry embraces many and varied industries and so rapid is the progress made in this branch of science, that almost daily new processes are introduced and present ones are improved and made more highly efficient.

Of the existing electrochemical industries, the greatest is copper refining, the electrolytic copper produced during 1903 being estimated at 318,000 tons, of which the United States produced 86 per cent.

The second in importance is probably the production of aluminum, the production for 1903 being approximately 7,500,000 pounds. Both of these industries have been successfully carried on for a number of years and are now firmly established.

Numerous processes have been brought forward for the manufacture of caustic soda and bleaching powder by the electrolysis of common salt. The two processes of greatest importance are the Castner-Kellner and the Acker, both of which are in use at Niagara Falls.

The Caster-Kellner apparatus consists of a slate tank divided by a slab or diaphragm of slate, which does not touch the bottom, but dips into a layer of mercury covering the bottom of the tank. The first compartment has a carbon anode, or positive pole, and is filled with brine, the mercury at the bottom forming the cathode. The second compartment is supplied with an iron

cathode, the mercury here serving as the anode and is filled with pure water, which is drawn off and replenished when in the course of operation it becomes impregnated with caustic soda. Sodium from the brine in the first compartment forms an amalgam with the mercury. A circulation of mercury between the compartments is effected by an eccentric device attached to the tank, which regularly raises and lowers one end slightly. Once in the second compartment, the sodium of the amalgam combines with the water to form caustic soda and hydrogen, the latter appearing at the iron cathode. The product obtained contains 97 to 99 per cent. of caustic, less than one per cent. of salt, and traces of sodium carbonate, sulphate and silicate.

The Acker process affords an interesting comparison with the one just described. It employs a fused electrolyte instead of an aqueous solution, and, therefore, requires for its operation a much higher temperature (850 degrees C.), while the Castner-Kellner operates at 40 degrees C. Molten lead is employed instead of mercury, and the resulting lead-sodium alloy is brought in contact with a jet of steam instead of cold water.

Castner's name is borne by another important electrochemical process, viz.: the production of metalic sodium. This element, though its salts are found abundantly in nature, does not occur as the metal, and its production, while frequntly attempted, has been until recently, a difficult and expensive undertaking. The development of the process and its present industrial importance are due largely to the efforts of Castner.

Most of the sodium produced to-day is by this process, which consists in the electrolysis of fused caustic soda. The metal, on account of its lightness, rises and floats on the surface of the electrolyte, whence it can be dipped off by means of perforated ladles.

A dozen years ago the principal source of demand was for the production of aluminum, but with the application of electrochemical methods to the aluminum industry, this demand has ceased.

To-day, the most important use of sodium is in the manufacture of alkaline cyanides employed in gold extraction. It is also largely employed in the form of sodium peroxide for bleach-

ing purposes, in the manufacture of certain aniline colors and in electroplating.

During the past two years, considerable attention has been given to the development and improvement of the methods for the electrolytic production of metallic calcium and the problem, which for a long time resisted all attempts, has at last been solved.

The product will find its greatest application in organic chemistry, where the need has long been felt for a cheap metal with reducing properties stronger than those of aluminum and magnesium and weaker than metallic sodium or potassium. The discovery should be of interest to the steel industry, replacing aluminum to remove the last traces of oxides from the molten steel, and it is only within the past month that the writer had a sample of aluminum-calcium alloy sent him for analysis. This should have wonderful reducing properties, making it much more desirable than aluminum alone.

Fifteen years ago the name of carborundum was unknown. To-day it has practically supplanted many other forms of abrasives. The inventor, E. J. Acheson, while conducting investigations regarding the production of aluminum, made some crystals of such intense hardness that he thought of their use as an abrasive, though he attempted no further development at that time. Later he undertook a more thorough investigation of the matter and, after some preliminary and highly successful experiments, he began, on a small scale, the manufacture of the substance, to which he gave the name of carborundum.

It had been noticed that in the case of overheating of the carborundum furnaces, some of the crystals next to the heating core and which were subjected to the highest temperature, were entirely converted into graphite. This suggested the method which, as now carried on, results in the production of pure graphite, having only a fraction of one per cent. ash.

The principal form of product is rods for electrodes, the raw material employed being petroleum coke. Graphitization of anthracite coal has also been accomplished, yielding a form of graphite valuable as a lubricant. Pure artificial corundum is also manufactured commercially by the fusion of bauxite in an electric furnace, and but a little more than a month ago a patent for

a new type of furnace for the production of artificial corundum was issued.

Another extensive use of the electric furnace is in the manufacture of calcium carbide. This, through contact with water, gives off acetylene gas, and the rapid development of acetylene gas lighting is largely due to the growth of the calcium carbide industry. Though a very simple synthetic process, there are many details which demand careful attention if the operation is to be successful commercially. The carbide is produced by heating together in the electric furnace a mixture of 65 per cent. lime with 35 per cent. carbon or coke.

In two departments of iron and steel metallurgy, the electric furnace has been commercially successful. In the manufacture of ferro-alloys, such as ferro-silicon, ferro-chromium, ferro-molybdenum, ferro-titanium, etc., it seems specially adapted to the required work by reason of the high temperature obtainable, while in the manufacture of special steels, its value lies in ease of control and the possibility of preventing impurities in the finished product.

Some of the most highly interesting of electrochemical investigations have been directed towards the fixation of atmospheric nitrogen. Vegetation of all kinds is dependent on nitrogenous food in the form of fixed nitrates. The natural source of supply is that formed by the decomposition of animal and vegetable matter, but under the conditions of modern civilization, this is rarely returned to the land but is burned or ultimately finds its way to the sea from which there is no return.

In view of this waste and the rapid failure of native nitrogen in the soil, we must resort to artificial fertilizers. These are obtained principally from nitrate deposits in Chili, from guano, certain rock deposits in the southern states and the new nitrate beds recently opened up in southern California. But all these supplies are limited and it has been estimated that in a quarter of a century, twelve million tons (12,000,000) of fixed nitrates will be necessary for the production of the world's supply of wheat.

New sources must then be sought and since nitrogen in the free state forms four-fifths of our atmosphere, it seems reasonable

to attempt some means of supplying the necessary nitrogenous plant food from this source.

The formation of nitrous vapors by the passage of electric discharges in the air is a phenomenon noted before the end of the eighteenth century in experiments by Priestly and by Cavendish, but the establishment of a scientific principle and its industrial application are usually widely separated, and it was not until quite recently that the fixation of atmospheric nitrogen assumed an important aspect.

In 1903, two German chemists described an experimental process for the production of nitric oxide by the combustion of atmospheric nitrogen in an electric flame.

In the United States, a process has been successfully established at Niagara Falls by C. S. Bradley and D. R. Lovejoy. The system has developed into the use of a large number of arcs operating in a closed air chamber through which a definite and carefully regulated volume of dry air is passed. This air, after being subjected to the effects of the arc, leaves the apparatus carrying nitric oxides and peroxides, from which nitrous and nitric acids are produced in a sprinkling tower.

George T. Moore says of the process: "With a power sufficiently cheap and with perfect machinery, there seems good reason to believe that in the near future it will be possible to place upon the market a manufactured nitrate of soda or nitrate of potash that will be superior in quality to the deposits found in South America, and that will also be reasonable enough in price to compete with the natural product."

The manufacture of fertilizers is doubtless the most important field for the process, but nitric acid plays such an important part in the manufacture of explosives, is employed in celluloid manufacture, and photography is dependent upon silver nitrate. Considering, too, the importance of nitric acid in the modern laboratories of our iron works and elsewhere, it can be readily seen that this industry, when well established, will be one of the most important developments of the period.

A few words regarding the production of electrolytic iron. The difficulty encountered in accomplishing the deposition of iron has prevented any great attention being paid to the indus-

trial development of this process. However, recent research at the Laboratory of Applied Electrochemistry of the University of Wisconsin has established the fact that electrolytic iron can be produced at such economy as to assure its commercial importance. The principal advantage of the process lies in the purity of the product obtained, as it is claimed that the resulting iron is 99.9 per cent. pure.

In the department of organic chemistry a late industrial development is the manufacture of ethyl alcohol from sawdust, which process has recently been reduced to an economical commercial basis. Methyl alcohol, the "wood alcohol" of commerce, has been for years obtained as a by-product in the manufacture of charcoal by the retort process, and even when carefully prepared and rectified, does not compare in value and wide range of application with ethyl or "grain" alcohol, hence the importance of the new process for the production of the latter. Before the development of the process here mentiond, ethyl alcohol had, in fact, been produced from wood on a small scale, experimentally, but by methods quite too expensive for industrial purposes.

By the process of Classen, sulphurous acid is used to convert the cellulose of sawdust into sugar and the sugar solution fermented and distilled, resulting in a good grade of alcohol. The cost was given as 13 cents per gallon of absolute alcohol, but it is claimed that with further development of the system, it would be possible to reduce this cost almost one-half. In the production of alcohol, a ton of wood is equivalent to ten bushels of corn. The residue from the sawdust is briquetted by pressure alone and charred, yielding the usual by-products, wood alcohol, wood tar, acetic acid and the charcoal in a convenient form for use.

In the line of medicinal products, many important syntheses have been made during the past few years. Successful efforts have been made to establish substitutes for some well known drugs, avoiding their injurious effects while retaining their desirable properties. Thus local anæesthetics have been sought and discovered which possess in a less degree the toxic or poisonous effects of cocaine and are otherwise more desirable.

A department of chemical research which, though it has invited extended investigation, has been slow to yield results is the chemical constitution of the vegetable alkaloids. With the definite establishment of these bases, the chemist requires only time to be able to prepare derivatives having similar action, or even to eliminate objectionable features and arrive at an action more desirable. Among these alkaloids, morphine especially has received much attention with the object of obtaining a derivative which would not produce the deleterious secondary effects of morphine. These efforts have lately been attended with a fair degree of success. In the case of quinine, too, successful attempts have been made to obtain derivatives free from the salts ordinarily employed.

For years chemists have sought a process of producing camphor synthetically (that is, to obtain the desired composition by the extraction, chemical treatment and combination of various principals.) Besides its importance in medicine, camphor is largely employed in various industries, three times as much being used in the manufacture of gun cotton, celluloid, photograph films, etc., as is used for medicinal purposes. The natural supply is insufficient and constantly diminishing, so the assurance that camphor can now be manufactured by artificial means should be of general interest.

The Ampere Electrochemical Company have at last devised a process which promises commercial success. Camphor and turpentine are almost identical in chemical composition, the only difference being one atom of oxygen contained in the camphor. The process consists in the treatment of turpentine with anhydrous oxalic acid, after which the resulting liquid is distilled with live steam in the presence of an alkali. The camphor is obtained comparatively pure but it is further purified by heating to the boiling point and blowing it, by a strong current of air, into a second vessel or "condensing pan," where it settles in pure white crystals.

It is quite the usual thing nowadays for natural substances to be prepared by purely chemical methods, so it is not strange that the artificial production of an article so important as silk should have invited attention. Artificial silk is now manufactured on quite an extensive scale, especially in France. Though

quite similar in appearance to the natural product, it differs from it in chemical composition and in other respects. All the varieties of artificial silk which are of commercial importance being made from pyroxzlin, a nitro derivative of cellulose. The pyroxzlin is dissolved in an alcohol-ether solution, two parts of 95 per cent. alcohol to three parts of ether. It is then carefully and repeatedly filtered under pressure to obtain a perfectly clear and pure solution. This solution is next forced through capillary glass tubes, a pressure of forty to fifty atmospheres being required owing to the viscosity of the fluid. As the thread emerges from the tube, the alcohol and ether rapidly evaporate, allowing the thread to harden. Several of these fine threads are collected into a single filament and wound together on spools. The silk as thus prepared is highly inflammable, and to remove this defect is de-nitrated by washing in ammonium sulphide. In tensile strength, elasticity and softness, the product is not equal to the natural silk, but is very lustrous, and being readily dyed, is suitable for upholstering and decorative purposes.

A method for making artificial cotton has been described recently. Fir wood is used as raw material and yields a product pliable and very satisfactory. Chemical research regarding the synthesis and artificial production of rubber has recently been attended with results highly favorable and especially welcome in view of the diminishing supply of the natural article.

And then that wonderful product, self-hardening steel, that has and will still further revolutionize machine shop practice. Where, everything else being equal in the steel, one-quarter of one per cent. of vanadium replaces from four to six per cent. of molybdenum and this again replaces from fifteen to twenty per cent. of tungsten and with the proper heat treatment, produces a steel of wonderful endurance.

And then what a fertile field for research work we have in coal tar, aside from the aniline colors that rival the solar spectrum in their gorgeousness, we have benzoic sulphimide, which under its familiar name, saccharine, has been a boon to thousands of sufferers from ill health who could not, with safety, use sugar, and then that valuable group of sleep-producing medi-

cines of which sulphonal is among the first and veronal is the latest discovery.

In addition to these there are an almost innumerable number of products which can be nitrated and which forms the basis of the modern high explosives, the best known being trinitrophenol or picric acid, being as its name indicates, nitrated phenol or carbolic acid, the most important and best known antiseptic and disinfectant.

Trinitrotoluene and trinitrocresol are also well known high explosives made in exactly the same manner as picric acid and having exactly the same explosive properties. Almost an endless number of compounds can be made by combining these various nitros with each other and these are the basis of innumerable explosives which have some fancy name.

The lyddite of the English is pure picric acid, while the melinite of the French is the same with the addition of about four per cent. of thick petroleum oil, which makes it very insensitive to shock.

When the writer was a student, there were sixty-five elements known that singly or in combination, made up this little world of ours. Now there are seventy-eight.

Ten years ago the scientific world was just settling into the comfortable consciousness that it knew all about the air that we breathe. Since that time, five new gases have been discovered in the atmosphere. And still the work is not done, still the scientist is working, sometimes in the darkness of the future and sometimes in the light of the past, reaching for the unknown, and that search will continue until the true constitution of matter is known.

BENDING STRESSES IN WIRE ROPES.*

BY SAMUEL DIESCHER.
Member Engineers' Society of Western Pennsylvania.

This paper relates to bending stresses as they occur in the wires of ropes bent around sheaves in the operation of hoisting machinery, inclined planes, cable railways, passenger and freight elevators, etc. It is herein assumed that the sheaves employed in such work are of diameters commensurate with the diameters of the ropes wound around them. According to a rule long since adopted in practice, sheave diameters shall equal, or exceed, 48 diameters of the corresponding ropes; that is to say, that for every quarter inch of the diameter of the rope, twelve inches is to be allowed for the diameter of the sheave. That this ratio is adequate is proved by the fact that when during the service of a rope in connection with a sheave of such diameter, a wire breaks, it does not immediately part, but the broken ends remain in touch for several days and so close to one another that the break is detected only upon very careful inspection when the rope is at rest. From this we are justified to infer that the grip the wires have on each other, by reason of the twist, is such that those ends are held close together even while the rope passes around the sheave. On the other hand, it is obvious that if the ratio between sheave and rope diameters were only 24 to 1, the fractured ends of that particular wire would part sooner, owing to more severe bending than with large sheaves. What the smallest diameter is that will yet answer, can be ascertained by experiment only. Moreover, as the ratio of 48 to 1 is in most cases permissible, with reference to local conditions, we take it for granted that the ropes and sheaves considered in our investigation are of right proportions.

It is not the intention herein to undertake to ascertain the effect of bends that cause permanent stretches, as for instance,

*Paper read before the Mechanical Section of the Engnieers' Society of Western Pennsylvania, January 3, 1905.

loops and kinks, but these investigations are limited to the consideration of working conditions as usual in practice. Abrupt bends cause lateral spreading of the strands and consequent flattening of the section of that rope. A rope repeatedly subjected to such treatment would rapidly disintegrate.

I am not aware that ever any extensive practical tests were made toward establishing the effect that bending has upon the stress among the strands and wires of a rope. And the experiments made in this direction were not pursued far enough to yield definite and reliable data.

It is in the interest not only of the users but also of the makers of wire rope that tests be made in this line, under conditions like those in practice. The parties most competent to do this are the manufacturers of wire rope.

In Mr. Kent's "Pocket Book for Mechanical Engineers" is given a formula for the calculation of bending stresses in wire ropes. It has also tables containing the results of calculations for various sizes of ropes and sheaves, but in that formula no cognizance is taken of the load hanging on such a rope, whereas, in fact, it takes more effort to bend a rope if taut than if slack.

It seems that this formula was made under the impression that in bending a rope the conditions are about the same as if bending a solid bar; for, according to those tables, the stress produced in the wires of a rope two inches in diameter, bent around a sheave eight feet in diameter, is 57,000 pounds. If this were correct, the breaking of ropes on inclined planes, elevators, etc., would be of daily occurrence, and necessarily the use of wire ropes for such purposes would have to be abandoned. The fact is, that the conditions prevailing in a wire rope while it is being bent, differ very much from those in a bar subjected to the same operation. If we take a bunch of straight wires arranged as shown in Fig. 1, tie them near one end by a tight fitting ring into a cylindric group so that the wires cannot shift relatively, and then bend that bunch, as shown in Fig. 2, the loose ends of the individual wires will not be flush any more, as they were before bending, but instead, the wires on the concave side of the curve are projecting while those on the convex side are retreating, and all wires between concave and convex side follow

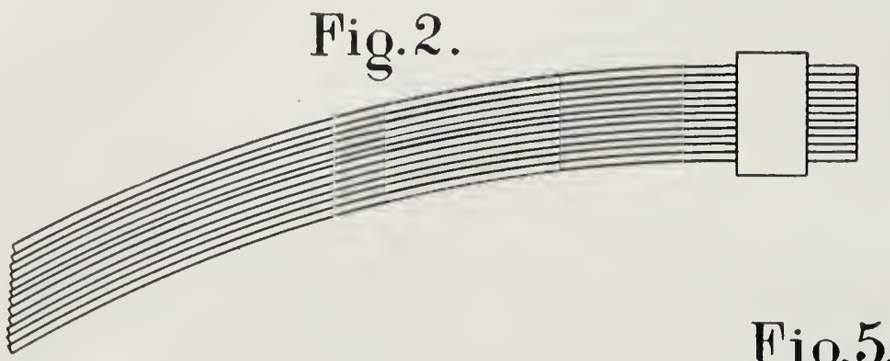

Fig. 2.

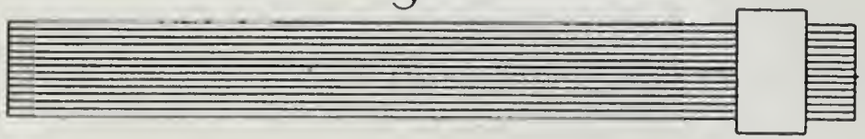

Fig. 1.

Fig. 5.

Fig. 3.

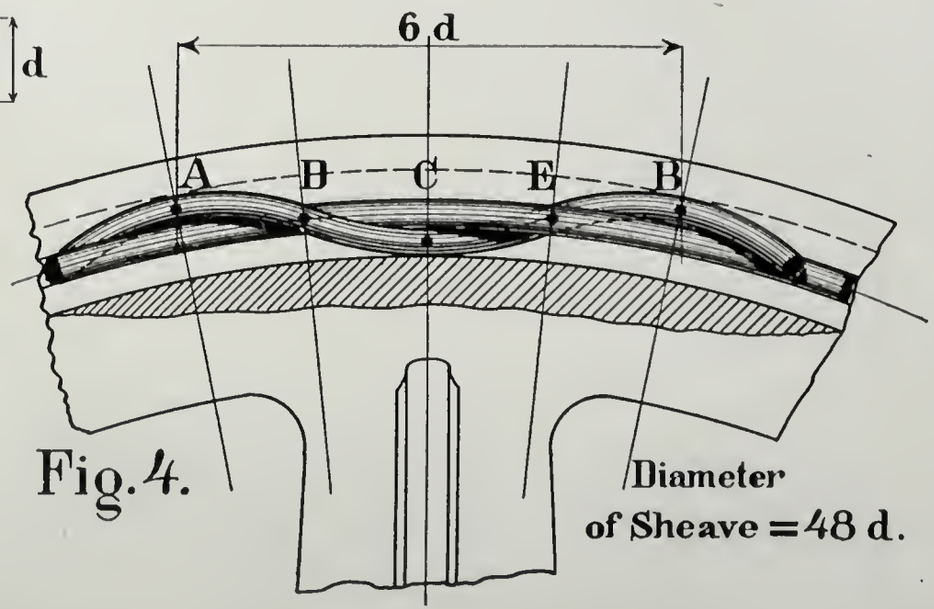

Fig. 4.

more or less according to their situation in the bunch with relation to the neutral axis.

The resistance experienced in bending that bunch of wires is equal to the sum of the resistances of the individual wires, for each wire acts as a spring, and if the bunch consists of 100 wires, its total resistance equals that of 100 springs each of the strength of a single wire. Now, let us take another bunch of wires of same number and size, but to have both ends firmly bound, as in Fig. 3. If we try to bend this bunch we encounter many times the resistance we found in the bunch having one end open. This difference arises from the circumstances that in the bunch with fixed ends the wires cannot accommodate themselves to the difference in length between inner and outer curve, but must respectively stretch and contract, or buckle on the concave side as in Fig. 3, but to do any of these acts requires much more effort than in the case of Fig. 1, where the wires could adjust themselves to altered conditions.

Now, let us see what happens if we bend a rope of, say, two inches diameter, around a sheave. Fig. 4 shows a fragment of wire rope that consists of six strands wound around a hemp center. As those strands are laid around the center in screw thread fashion, all are subjected to precisely the same distorting and straining effects; consequently, whatever happens to one of those strands happens to all, therefore, we shall confine ourselves to the consideration of one strand instead of six of them.

Fig. 4 shows how a single strand lies around the hemp core. Its length is that of one turn around the core. The length of such a turn usually equals six diameters of the rope. Thus in a rope of two inches diameter the distance between corresponding points in one and the same strand is 12 inches.

By the act of bending, the point C of the strand is pressed against the rim of the sheave, the arc D C E flattens and the space D E spreads. If at this occasion the points D and E were firmly held, the flattening of that arc could not occur, except to the extent that the compressibility of the material in the strand would permit. But since the points D and E are not fixed, and that the arcs A D and E B are in tension, and further, that through the bending of the rope the chords A D and E B must expand as

much as the chords D C and E C must contract, therefore, compression cannot manifest itself, because any pressure at C must necessarily forward the local surplus toward points A and B. Hence the tension that occurs under ordinary conditions in the fibres of the convex side of a bent bar, is, in the case of a rope, neutralized in the manner that the increment which the upper fibres lack is drawn from the concave side of the rope whence an equal increment is displaced, by reason of the shortening of the arc D C E, contingent to the act of bending.

Compression in that arc D C E could take place only under the condition that the points D and E act as abutments, but since those points readily yield, therefore, the surplus in arc D C E is at once transferred beyond the points D and E, to where it is required to prevent tension.

In this manner the bending of the rope takes place without severe stress in any part of the strand, because the increase in the outer circumference over that of the neutral axis of the rope is supplied by the corresponding decrease of the inner circumference. This compensation occurs locally, within every turn of the strand. The tendency to pull in the upper part is equal to that to shove in the lower part, and as both these forces lie in one and the same line and act in the same direction; therefore, neither opposes the other, but, on the contrary, they act in accord, with a common result. Hence, as far as these two forces are concerned the movements within the strands would meet with no resistance at all, but owing to the fact that all strands are in close contact with each other and the rope is in tension due to the work it performs, therefore, there is a certain amount of friction to overcome when the strands adjust themselves to altered conditions.

Considering a two-inch rope, and a sheave of eight feet diameter, the difference between inner and outer circumference of the coil of rope, and that of the sheave is $4 \times 3.14 = 12.56$ inches $= 1.04$ or, say, one foot. But the rope as laid around the sheave, measured along its neutral axis is already $2'' \times 3.14 = 6.28$ inches $= 0.52$ feet, longer than the circumference of the sheave, therefore, the elongation that occurs on the convex side of the rope during one revolution, is half a foot, and in accord with this, the contraction on the concave side of the rope is also half a foot, and likewise

is also the whole adjustment during one revolution of the sheaves half a foot of all of which compensation takes place in the manner that the excess of the concave side is shifted to the convex side, and this takes place while the rope changes from a straight line to a circle. This motion is the aggregate of all motions in one strand that occur during a full revolution, and must take place under the pressure the rope exerts against the rim of the sheave which in turn reacts upon the rope and its strands. The resistance that opposes this motion is friction among the strands as they rub against each other.

The intensity of this friction depends upon the pressure applied and the coefficient of the materials in contact. The coefficient of a steel rope upon a cast iron finished surface is 0.13. To be entirely safe, let us assume it to be 0.15.

The pressure that a rope exerts upon the circumference of a cylinder, of no matter what diameter, is 2×3.14 P per full coil. In this formula P represents tension in the rope due to its load. In the present instance let us take that tension at 30,000 pounds. Hence the aggregate pressure that one coil exerts upon the circumference of a cylinder, or sheave is: $2 \times 3.14 \times 30{,}000 = 188{,}400$ pounds. The circumference of an eight-foot diameter sheave is 25 feet. Hence the pressure upon one foot of circumference of this sheave is 7,216 pounds, or say, 7,200 pounds.

In a rope of two inches diameter a strand makes one winding around the core in 12 inches; therefore the compensation between compressed and pulled parts of that strand must also take place within the length of 12 inches, and as this compensation is continuously occurring and that there are always exactly 12 inches of that rope affected, it is evident that the resistance opposing that readjustment is the friction produced by the pressure upon 12 inches of that circumference of the sheave, but since this pressure is 7,200 pounds, the friction thus produced is $7{,}200 \times 0.15 = 1{,}080$ pounds. As there are six strands in the rope and at all times engaged in the act of adjustment, we must multiply the resistance by six and thus get $6 \times 1{,}080 = 6{,}480$ pounds as the total bending stress in the rope.

The power consumed in doing this bending is the bending stress multiplied by the amount of motion in the strands during

the process of adjustment in one revolution. We saw before that the whole movement of the strands within one coil of the rope on the sheave is 0.5 ft., consequently the work of bending is 0.5 x 6,480=3,240 foot pounds.

Applying this to a practical case, say, an inclined plane of 1,000 ft. length, or a shaft of this depth, the same sheave will make 1,000÷25=40 revolutions, and as it takes 3,240 foot pounds per revolution, the power consumed during one run in performing the work of bending the rope, is 40 x 3,240=129,600 ft. pounds. If this run is made in one minute, the power spent is 129,600/33,000=3.93 say, four-horse power; if made in two minutes it takes two-horse power, etc.

If, for example, we were to use a sheave of only four ft. diameter, the total pressure the rope would exert upon the rim of the sheave is the same as if that diameter were ever so large, but as the circumference of that sheave is only half as much as that of eight ft. diameter, therefore, the pressure per lineal foot of the rope is twice as great, and, consequently, the friction opposing the adjustment of the strands is double that in the other instance. This alone is sufficient reason to select large diameters for sheaves, but in addition to the double friction, we must take into consideration also that with the four foot diameter sheave, the compensating motion of a strand in a given length of rope is twice as great for the same length of rope as with the eight foot sheave, therefore, the energy consumed in using a four foot sheave, is four times that required with an eight foot sheave. In short, the resistance opposing the adjustment of the strands grows inversely with the square of the diameter of the sheave. Both instances refer to the same velocity of the rope.

In figures 6 to 11 we see the difference in the length of compensating motion instrands required by reason of the difference in the diameter of two sheaves. Fig. 6 represents a sheave of 60 inch diameter and Fig. 9 one of 30 inches diameter. Figures 8 and 10 show in exaggerated scale the relative differences between outer and inner arcs of a rope, in a length of six diameters: and Figures 7 and 11 show the amount of compensation required in each case. By the use of a scale we find that those lengths are inversely as the diameters of the sheaves.

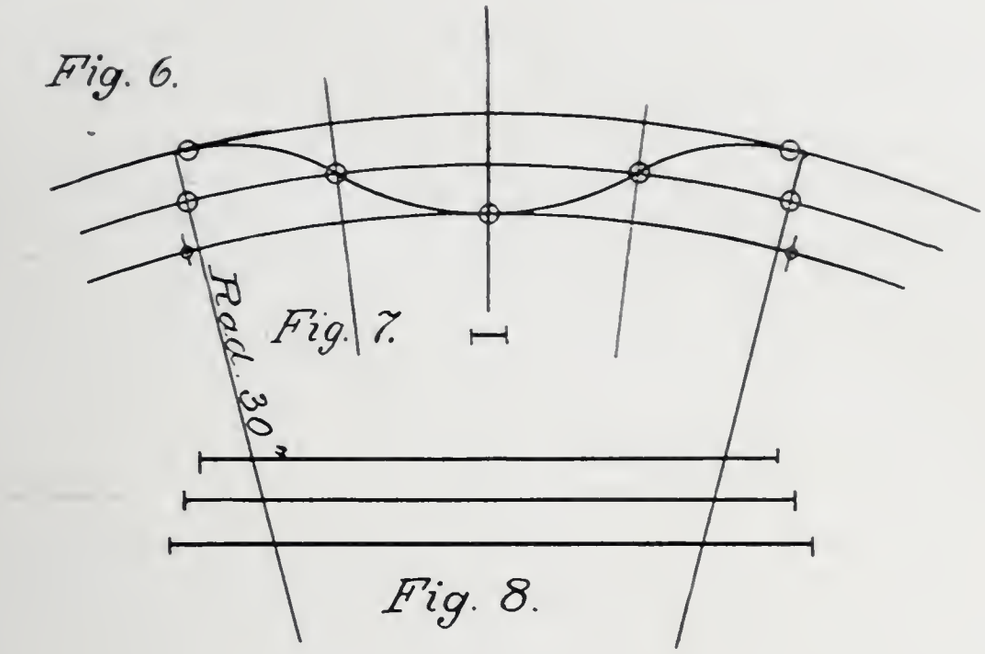
Fig. 6.
Rad. 30"
Fig. 7.
Fig. 8.

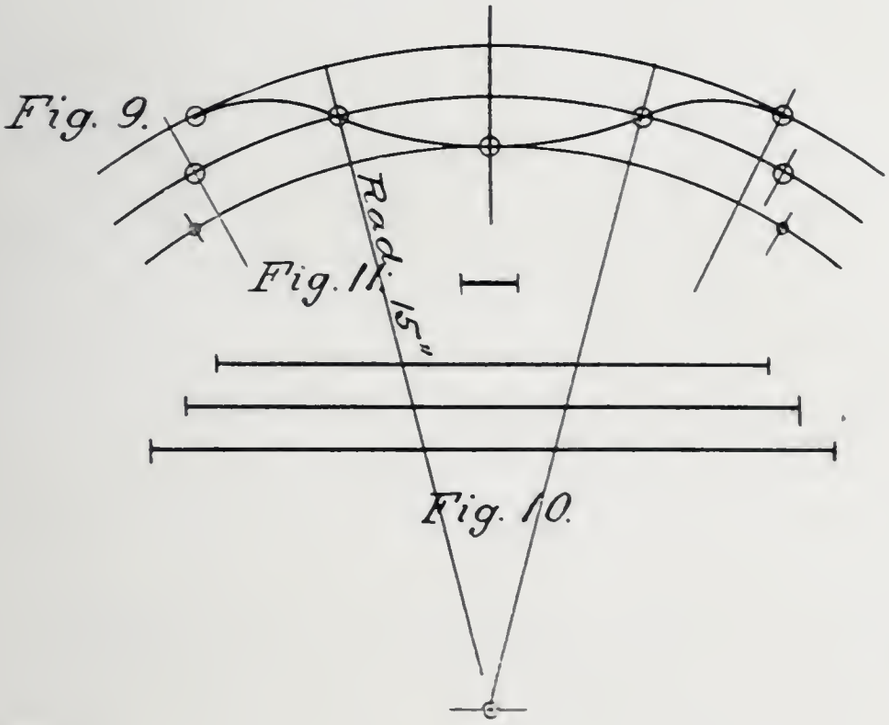
Fig. 9.
Rad. 15"
Fig. 11.
Fig. 10.

In connection with the bending act it is to be said that the straightening of the rope does not require any external force, because in the act of bending the elastic resistance of the strands must be overcome, whereby energy is stored in those strands in the same manner as by compressing or stretching a spring which resumes its original state upon being released. Therefore, the energy required to straighten the rope is imparted to the rope while it is being bent.

It stands to reason that there is a limit to the compensating capacity of the strands in a rope, but where that limit lies can be determined only by actual trials under working conditions. This task by right falls upon the manufacturers of wire rope, in whose interest it is to furnish their customers reliable information concerning the proper use of wire rope.

DISCUSSION.

Mr. C. B. Albree, M. Eng. So. W. Pa.—Mr. Diescher tells us that "The intensity of this friction depends upon the pressure applied and the co-efficient of the materials in contact. The co-efficient of a steel rope upon the cast iron finished surface, is 0.13. To be entirely safe, let us assume it to be 0.15. Now if I have not misconceived the argument the resistance is due not so much to the friction of the rope and the sheave as it is between the strands of wire upon each other, and it seems to me that that co-efficient is the one that has bearing on the case, rather than the co-efficient of the wire where it happens to come in contact with the sheave. Nearly the whole length of each wire does have friction with the other wires.

Mr. Samuel Diescher—I do not know what the co-efficient of friction between smooth steel wire is. It stands to reason that it is less than that between the rope and the cast iron sheave, which is 0.13. However, I took 0.15 in the calculation, first to be sure that it is enough, and second, because the formulas given for the calculation of bending stresses give such remarkably high stresses, that I felt induced to be liberal and entirely safe in my calculations.

Concerning the question as to whether the friction is not due more to the relative motions of the strands among them-

selves than between them and the sheave, it is to be said that there is no relative motion between the rope and the sheave. After the rope has once taken hold of the sheave no slipping takes place; therefore, all the friction here considered is within the rope, that is among the strands.

Mr. A. Stucki, M. Eng. So. W. Pa.—The advantages of the large drums have been very wisely pointed out by Mr. Diescher, at least the difference in the relative work done in each case.

There is still another advantage in as much as the pressure between the rope and the small sheave is greater than that existing with a large one. This in turn increases the friction between the strands and prevents the relative movement to a greater degree, which means, that the tensile stresses in the top strands are that much greater than the compressive stresses near the sheave. This being the case, it is clear that a position of a rope on a small drum is subjected to a greater tensile stress than otherwise, naturally shortening the life of the rope.

Mr. Samuel Diescher—There are a number of advantages to be gained from large sheaves, namely: In a large sheave the total radial pressure exerted by the rope during one coil all around, is precisely the same as in a small sheave no matter how small. Therefore, if we consider a segment of the sheave's rims lying within the same central angles of two sheaves of different diameters, we find that, according to the foregoing, the short arc of the smaller sheave is subjected to the same pressure as the larger arc of the other sheave. But in as much as the smaller sheave must turn oftener in paying out the given length of rope, any particular point in the circumference will come in contact with the rope that much oftener and must wear out that much sooner.

Accordingly, if we consider two sheaves whose diameters are as two to one, the smaller sheave suffers twice the pressure per unit length of the circumference and comes twice as often in contact with the rope and thus suffers four times as much wear as the larger sheave while rendering the same service. Precisely the same proportionate disadvantage attends also the work in turning the sheaves. The large sheave makes half as many revolutions as the small one, hence has but half the journal fric-

tion to overcome and since the radius is twice that of the small sheave a pull at the rim is twice as effective. Therefore, it takes twice the power to turn the small sheave once around that it takes for one revolution of the large sheave; and the small sheave turns twice as often for the same length of rope travel, consequently it takes four times as much power for the same work performed as in the case of the large sheave.

The effect on the bending stress is: that since in the sheave of half the diameter of the large one, the compression and consequent friction among the strands is twice that in the large sheave, and since as shown in Figures 6 to 11, the relative motion during compensation while the rope is being bent, is twice as much for the same length of rope in the small sheave as in the large one, therefore, in this respect, too, the advantage lies decidedly on the side of the large sheave.

The foregoing statements imply that in sheaves of different diameters "the wear and tear of the rim, the power required to turn the sheave, the work required in binding the rope, each grows invariably with the square of the diameter."

Mr. J. L. Klindworth, M. Eng. So. W. Pa.—In getting the amount of the friction opposing readjustment, Mr. Diescher multiplies the result he gets by six. It appears to me he should only take 1,080 lbs.; although he has a total pressure of 1,080 lbs. divided among six strands. One could imagine, for instance, eight ropes of a single strand around a center laid alongside each other, and the total pull would be only 1,080 pounds. I don't see that it should be multiplied by six after that.

Mr. Samuel Diescher—The rope consists of six strands, the working strain in the rope is sustained by all of them equally. The strands are so wound around the center that,—where the rope as a whole presses upon the sheave that pressure goes transversely through all strands simultaneously. The strand that just happens to lie against the sheave is pressed by the sheave as well as by the center strand of the rope. Beyond the point where that strand touches the sheave, it is pressed by its two neighbors. But so is every strand pressed by its two neighbors. It follows that whatever adjustment occurs there, must take place in opposition to the friction exerted by any two strands upon the one between

them and as every strand has two neighbors transversely pressed and all of them within twelve inches are in motion under friction, therefore, the friction found to occur in the one strand considered occurs also in the other five strands. The conditions are the same as if from a bunch of rods tightly pressed together, a single one were drawn out, no matter which one, they are all pressed alike and therefore under the same friction.

Mr. J. L. Klindworth—Then if you had a two inch rope and say twelve strands, you would have twelve times the friction. As a matter of fact, a rope of a certain diameter with many strands bends more easily than one having fewer strands.

Mr. Samuel Diescher—If we lay six flat bars of a certain length on top of each other and so press them together as to cause considerable friction, then pull the bars out, one by one, we shall find that the labor required in singly pulling them out is the same as if one bar of the length were pulled under six times the pressure applied upon the six, or one bar under the same pressure but of six times the length of a single bar. This applies also to twelve bars or twelve strands in a rope.

Mr. C. A. Lindstrom, M. Eng. So. W. Pa.—I would like to know whether the proportion of 48 times the diameter is considered good practice with ropes for all kinds of service? I know from experience that 30 times the diameter gives very good results in crane service.

Mr. Samuel Diescher—In cranes they are bound to limit their sheaves to small dimensions because prevailing conditions would not permit larger ones. But those ropes wear out faster than if the sheaves were larger.

Mr. C. A. Lindstrom—Yes, but at the same time 30 times the diameter gives very good service and the ropes can be used for several years. I grant that on inclined planes, for instance, where the service is practically continuous and stresses are maximum at all times, that 48 times the diameter is to be preferred, but in crane service where the load is variable, 30 times the diameter will give very good results.

Mr. Samuel Diescher—As a rule inclined planes will not strain a rope too high, rarely more than one-sixth of its strength.

MR. L. C. MOORE, M. Eng. So. W. Pa.—Up to six years ago, a two inch Swedish iron rope was supposed to be run safely on an 8 ft. sheave, whereas a 2 inch plow steel rope required a 16 foot sheave. Since then the tables of the wire rope manufacturers have been changed and for a Swedish iron rope, which has a tensile strength of 48,000 to 54,000 lbs. per square inch, they now recommend a 12 foot sheave, whereas with a plow steel rope 2 inches in diameter having a tensile strength of 250,000 lbs. per square inch, they recommend an 8 foot sheave.

MR. SAMUEL DIESCHER—It looks as though the first time, when they asked for a 16 foot sheave the plow steel was probably so brittle that they did not trust it on a small sheave. Since then they must be making a steel that is not only stronger but more elastic than what they use in so called crucible steel ropes. It must be a steel they did not make before.

MR. G. H. CAMPBELL, M. Eng. So. W. Pa.—A rope as usually made consists of so many strands, and each strand of so many wires: does Mr. Diescher mean to say that this same argument applies to a rope of six strands each of 19 wires?

MR. SAMUEL DIESCHER—Yes.

MR. G. H. CAMPBELL—The strand is not used as a whole?

MR. SAMUEL DIESCHER—Yes.

MR. G. H. CAMPBELL—In elevator service very frequently on examining a defective rope after taking it off, we find the wires are cut on the inside as much as on the outside. So the strand does not move as a whole, but the individual wires move.

MR. SAMUEL DIESCHER—The inner wires are pressed into hexagonal shape, but not worn, whereas, the outer wires are worn flat on the exposed surface.

MR. G. H. CAMPBELL—That wear must be due to friction then?

MR. SAMUEL DIESCHER—If this were so then the inner strand would break simultaneously with the outer wires, but in my connection with inclined planes during more than thirty years, I only once found the inner wires of a strand broken. In that particular instance all the outer wires were broken into pieces of 2½ inches in length, pointed at both ends like tooth picks.

MR. L. C. MOORE—The seven inner wires are shorter than the 12 outside wires but I think the friction is just as great on the inside wires as it is on the outside wires, because in looking after the claim department of one of the large manufactories for some eight or nine years, I found in many instances where the rope was nearly worn out, that the inner wires were just as much worn as the outer wires, but only in cases of extreme wear.

MR. G. H. CAMPBELL—Is that 1,080 lbs. the total stress due to the bending around a wheel in this particular case?

MR. SAMUEL DIESCHER—Yes, sir, in one strand.

MR. G. H. CAMPBELL—In a rope of 2 inches there is considerable area in a strand and 1,080 lbs. would not be worth considering as additional stress. The wear on the rope is due entirely to the load put on it.

MR. SAMUEL DIESCHER—The wear is due to the rubbing of the strands against each other; also rubbing against the flanges of the sheaves; in the rubbing of coil against coil as the rope is wound around the drum, and the wear from the track sheaves.

MR. C. B. ALBREE—In your practice you find no material slip on the sheave itself and your sheave is supposed to be well oiled?

MR. SAMUEL DIESCHER—Even if the sheaves are well oiled there is no slipping on them, although only a comparatively small arc is covered by the rope. As a rule sheaves turn readily.

THE USE AND ABUSE OF WIRE ROPE.*

BY L. C. MOORE.
Member Engineers' Society of Western Pennsylvania.

It is thought best to confine this paper to a discussion of cast steel and the higher grades of wire rope, and it is also considered that the same may prove more interesting if a short explanation of the methods of preparing wire for these grades of rope is prefixed.

Nearly ninety per cent. of all the stock of steel for rope wire is imported either in the form of billets, wire rods, or partially manufactured wire. Steel rods for rope are always larger than No. 6 BWG (.203″), owing to the comparative higher tariff on smaller sizes.

The analysis of wire rope rods is, viz., either acid or steel for cast steel rope.

	Carbon.	Manganese.	Silicon.	Phos. not above.	Sulphur not above.
For extra strong....	47 to .58	.20 to .30	trace	.035	.035
Or plow steel.....	65 to .70	.35 to .50	trace	.035	.035

The rods are cleaned, i.e., the scale and rust, if any, removed by means of sulphuric acid diluted with say 95 parts of water which is heated to a boiling point. The coils weighing from 60 to 100 pounds are immersed in the tubs on wood reels and the process of cleaning usually requires about thirty minutes. They are then removed by hooks or crane and thoroughly washed with water and kept wet until they are *water coated.* This term is more clearly understood by the following explanation: that the rods being entirely free from scale and rust immediately commence to oxidize again and if kept wet for sometime a coating forms on the surface that is afterwards utilized in drawing or reducing to the diameters required. After they have been thus prepared they are thoroughly coated with a solution of lime, commonly known as white wash, and of course further oxidization is at once prevented, provided, however, they are in the meantime

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carefully dried. The rods must now be baked, as during the cleaning process they have taken up a certain percentage of an element from the sulphuric acid and they can not be drawn until all of this has been eliminated, and this can only be done by baking, and requires a heat of about 400° Fahrenheit and for a period of not less than 10 hours. Elaborate experiments have so far not developed any superior or quicker process than that above mentioned.

The rods being ready for drawing or reducing in diameter we will, in referring to such reduction, use decimal parts of an inch as being more comprehensive than numbers as applied to the wire gauge. As before stated, they are about .200″ in diameter and are first drawn to .150″—.155″. This is accomplished in two reductions or drafts, one wire drawer operating two wire blocks, the first draft from .200″ to .165″—.170″; the second draft reducing .150″—.155″. In this connection the peculiar features of the wire drawing plate are considered first. They are sometimes made of what is commonly known as white cast iron, but the plate principally used is made of a special steel, and for the larger sizes perforated with 18 conical shaped holes which, owing to the peculiar nature of the metal can be opened or closed at will by the operator, who uses a hammer and a perfectly round, high tempered and polished steel punch, carefully ground to just the right taper. This feature requires not only skill but a knowledge of certain peculiarities of the stock to be drawn; it being a fact that steel comparatively high in carbon and manganese can not be successfully drawn with the same tools as low or .08 carbon stock.

Referring again to the nature of the steel from which wire drawing plates are made, it is very low in carbon, will not take any temper, therefore soft enough to permit cutting readily with an ordinary cold chisel, and, as before stated, the holes can be closed or opened at will without heating the plate. Yet, notwithstanding the above, steel wire rods .60 carbon and upwards, coils weighing even 100 pounds, and more than 1,000 feet long can be drawn through a properly prepared hole in a drawing plate, reducing the diameter of the rod from .200 to .170″ without enlarging the hole more than .003″, and this is common practice in all mills. It will be noted that this reduction necessarily

hardens the stock to some extent, but does not injure it because the elastic limit has not been passed, and without any additional treatment the coil will undergo another reduction from .170″ to .150″ or .155″; and if the drawing plate has been properly prepared this takes place without enlarging the diameter of the hole more than .005″, and by this time the steel has been hardened to such an extent that further reductions can not be made without injury until the stock has been annealed or tempered, also recleaned, coated and baked. If the former, this must be done with what is called a muffler, this being a furnace so constructed that coke, oil or gas can be used as fuel; soft coal being too high in sulphur for the purpose. The furnace must also be so constructed that no iron in same lower in carbon than the stock itself comes in contact with the wire, because if so the tendency will be to decarbonize and thus injure the latter.

Therefore it follows that a better grade of rope wire can be made by not using this form of annealing, but rather the continuous or tempering process, by which means no dangerous flames or fumes of any description can come in contact with the wire, thus preserving all the elements that are advantageous in making the best rope wire. Another feature of this latter process is: The wire being drawn into the heating tubes of the furnace from the coil, the heat of same being kept at exactly the proper temperature, with careful regulation and a good pyrometer, there is no danger of injuring same by oxidization, because as the wire is drawn out of this furnace it is not exposed to the normal atmospheric conditions outside until cool enough so that any such contact would have no effect whatever on the stock.

After reducing the rods from .200″ to .155″ tempering or annealing by the continuous process, again cleaning, coating and baking the wire even with more care than the first time, the stock is now ready for a further reduction. This is accomplished in exactly the same manner as the former, the tools used being smaller in size and diameter only. Also after the first drawing and continuous annealing process it is a fact that the quality of the stock has been improved, and this being the case the wire can be reduced four or even five drafts without annealing or injury; not such a severe reduction in parts of an inch, however, but just

as much or more proportionately to its diminished area as before. Rope wire of .155″ diameter after being properly treated can be reduced to .097″, after which, if further reductions are required. it should be treated in precisely the same manner as those already described.

All of the various stages of reduction from .200 to .097″ referred to above have also served another purpose; that of locating flaws or points low in tensile strength, as it is a fact that the strain required to reduce a cast steel rod from .200 to .170 one draft is equal to 15 H.P., and so on proportionately to all the smaller diameters. Therefore, this all indicates that by the time the wire reaches the inspecting and testing departments nearly, if not quite all the inferior stock has been discovered, rejected as rope wire and to be used for some such purpose as finer or market wire.

In treating the subject, "The use and abuse of wire rope," the best quality of cast steel or rope of any prescribed strength is that in which the wires of same are the most uniform in the bending and tensile strength tests. As stated in a former paper, neither torsion nor elongation as tests are of any importance in determining the quality of rope wire in the testing department. If the manufacturer in making up a stock reel of say $\frac{5}{8}$″ diameter 6×19 cast steel rope permits a variation of more than five per cent. in tensile strength and the same in bends, then this rope will not in all cases show good service, but if both tests are confined to say two per cent. variation in each direction, the quality of the stock reel will be perceptibly improved. All practical minds will agree that if wire is used in rope varying from 160 to 180,000 pounds per square inch in T. S., there will be a difference in resistance to bends. Therefore it follows that it is not always safe to depend on determining the probable life of a partly worn rope by counting the number of exposed broken wires to the foot or yard. Neither does it follow that because, say one-half of all the wires exposed are broken that it is time to abandon its use or procure a new rope, because it may be that the factor of safety is high and we must admit that with one-half of all the wires broken the rope is more pliable than when new; and to sum up the fact of one-half the wires being broken usually proves that either a smaller dia-

meter or more pliable rope should have been purchased in the first place. There is an impression that sometimes a rope is made with a bad spot in it running say several hundred feet long. This is utterly impossible and the reason therefore is as follows: Take for instance a piece of $\frac{5}{8}''$ diameter 6×19 cast steel rope, which would be a total of 114 wires in all. Now the size of wire used for this rope weighs 23 pounds to the mile, and as before stated, drawing same several different times has developed the majority of bad spots; and even if not, it is impossible in a mile or more of rope for these spots to come near enough together to cause any damage, and also because it is a fact, as has been demonstrated, that a test specimen with more than half of the exposed wires broken has shown a tensile strength of 90 per cent. of the original. It is undoubtedly a fact that more mistakes are made in buying a rope too large in diameter than too small for the service, and also in selecting one made of seven wires to the strand instead of 16 or 19 wires. Referring to six strands of 12 wires each, this style of rope should never be used except for standing or guy rope. Neither is there any decided advantage in the use of what is known as "Lang Lay," or so-called patented ropes, except from the possible fact that the manufacturers thereof are in some instances sharp enough to use a plow steel grade of stock in so-called cast steel rope and thus make a temporary record; and there is no known trade mark of rope that has proven itself superior to any other, and in fact the consumer must depend entirely on the honesty of the manufacturer from whom he buys his rope. He may in installing a new plant purchase a rope from "A" and when same is worn out buy another from "B." Now it may be possible that the second rope does not give as good service as the first one, therefore he makes his third purchase from "A" again; and this last rope may give more unsatisfactory service than the first rope from "A." Usually this can be explained by the fact that the plant, that is the sheave wheels, have not been kept in as good order as when first installed, or possibly the tonnage has been increased. Still the consumer of wire rope is not always at fault. It more frequently happens that the dealer or agent who sells the rope unintentionally makes a mistake in case the customer is not posted and recommends a style not exactly suited for the

purpose. This possibility is gradually decreasing, owing no doubt to the fact that profits on sales are gradually being reduced, and there are not so many dealers or agents for wire rope as formerly. As to the matter of claims for considered defective rope the manufacturer in making a stock reel usually keeps a record of same and any length of time afterwards it is possible to ascertain to whom each and every piece of this rope was sold. Now if this reel originally contained 20,000 feet and was cut up and sold to say eleven different customers, ten of whom keep quiet and the eleventh customer complains, it is hardly possible for him to prove his claim.

Too much can not be said regarding the care of wire rope. It requires lubrication just the same as high speed journals. Of course conditions usually prevent any such treatment, but to insure the best results the rope, if made to order, should be thoroughly lubricated when the strands are being laid up into a rope; and if so treated and afterwards kept well saturated on the outside with any kind of cheap lubricant that is free from acids, good results are bound to follow. The same diligence should be exercised in looking after all sheave wheels. They should be balanced, as nearly so as is possible, bored true with deep wide flanges and the grooves kept lined with Russia hemp or other fibrous material. It is not good practice to run wire rope in chilled iron groves, or even cast iron grooves, but if iron must be used, either a low steel or wrought iron lining should be specified for the grooves.

DISCUSSION.

Mr. A. Stucki, M. Eng. So. W. Pa.—If the rope manufacturers keep such a record as has been described by Mr. Moore, I think it won't be long before we may be able to get up specifications that will enable us to tell what we really want. We have been in the same predicament in regard to certain other materials. For instance: oil, waste, wheels, rubber hose, etc., and in all cases specifications have finally been drawn and have proved to be a good thing for the manufacturer, as well as the customer, it seems essential to have such specifications for wire ropes also.

Mr. L. C. Moore—That is a point that is well taken. It is absolutely impossible, however, as the manufacture of wire rope

in this country is confined to six or eight concerns. They are sharp enough to bind themselves together in such a way that their breastworks are well nigh impregnable. You have got to buy their rope or let it alone. There is no way for you to determine whether or no the piece of rope you are about to buy is good, bad, or indifferent, until you buy it and wear it out. If you got up such specifications and if they were prepared the same as they are drawn up in other lines, you would find that the manufacturer would again fortify himself in some manner, just as he fortifies himself now, by keeping a record of the rope. He does not do that to protect his customer, but himself. And you will find that every manufacturer in this country can tell you exactly the quality of the wire and reel of rope made ten years ago and where the stock in it came from. If necessary, they can show you the tests for that particular reel of the rope. Not because they care anything about the public, but to protect themselves. I don't think any of them want to make a bad rope, but they don't want you to know too much about their business.

Mr. H. Hallsworth, M. Eng. So. W. Pa.—I understand that at the present time there is only one really satisfactory way of socketing a wire rope. I refer to the method of fraying out the strands and wires, thoroughly cleansing them, bending the ends over and casting the whole in a socket with babbitt or similar metal.

My experience in testing wire rope proved this to be the most effective fastening and to be stronger than the rope itself as the fracture was always between them.

Mr. L. C. Moore—That plan of socketing a rope is used in the field where they don't have facilities for socketing a rope in any other manner. The correct way of socketing a rope is, after the ends of the wires are thoroughly frayed out, they are cleaned with muriatic acid and inserted in a socket, a round tapered pin, also cleaned with muriatic acid, is inserted and driven home. Then a preparation of hard solder, or type metal poured in and the whole mass soldered together in such a manner that it has probably the full strength of the rope. One of those sockets has never been known to pull out.

Mr. Samuel Diescher, M. Eng. So. W. Pa.—I saw sockets fastened to ropes in this manner. After the rope's end was put through the socket, the strands and wires were untwisted, the hemp center cut out, then tapered steel pins, approximately of the size of lead pencils, were driven into the spaces between the wires, and when no more would go in, lead was poured into the interstices and finally the ends of wires projecting about ¾ inches from the socket were bent around flat and driven home with a hammer.

I saw an interesting way of socketing a rope on the Ashley planes. A steel cone is used that is polished on the inside. This cone is sunk into a big casting. The rope is put through the hole and spun over on the rear side of the cone, with several layers of marlin. This is so laid on as to form a cone of the same taper as that of the bore, of course, the marlin is put on under considerable tension and with great care. When this is done, the rope is withdrawn bringing the marlin into the bore of the cone.

Mr. L. C. Moore—Thirty-five years ago when those planes were built that was the practice, and it is a very good way for a Swedish iron rope. It would not stand a month with a plow steel rope. Those people still use a 2½ inch Swedish iron rope when a 1½ inch plow steel rope would last twice as long.

Mr. G. E. Flanagan, M. Eng. So. W. Pa.—Mr. Moore says, "A test specimen with more than half of the wires broken, has shown a tensile strength of more than 90% of the original." In what length of rope may that occur?

Mr. L. C. Moore—In a test specimen ten feet long, if the lay is eight inches and there are 114 wires in the rope and 57 of them in that eight inches appear broken on the outside, it is safe to conclude half of the wires are broken. Such a test specimen, although no more than ten feet long, of cast steel rope, has been known to show a tensile strength of 90% of its original strength. That proves that the wires in breaking, break square off but don't pull apart until the friction wears both ends smooth. When both ends wear smooth, so they can get by each other, then they open out. But I will venture to say that wires will be broken long before the ends will separate. You could not pull the wire out of the rope.

MR. G. E. FLANAGAN—What is the action that breaks the wire in the first place?

MR. MOORE—Bending and friction. That is why I speak so strongly as I do of lubricating. If all ropes were kept properly lubricated they would not wear out so fast.

MR. F. S. JACKMAN, M. Eng. So. W. Pa.—Mr. Moore states that it is not possible to make wire rope out of true crucible steel. What is this so-called crucible rope?

MR. L. C. MOORE—I don't think there is such a thing as crucible cast steel rope. It is practically impossible to make wire out of this steel, so far as I know. I never knew of anybody being able to draw crucible steel successfully of the kind and quality such as is made for high grade tool steel or any other of the high grades of steel. But that would, of course, depend very materially upon the amount of carbon; on whether or not it was above 100. The best piano wire is usually made from above 80 or 90 carbon. That is frequently run up to a tensile strength of 350,000 lbs. per square inch.

MR. F. S. JACKMAN—What is the distinction between plow steel and the other steel?

MR. L. C. MOORE—Plow steel is higher in carbon and manganese. Carbon and manganese are used as antidotes for the inferior elements of the steel, such as silicon, phosphorus and sulphur. The higher the carbon and the higher the manganese comparatively, with low phosphorus and silicon will produce the best stock for wire rope.

MR. H. C. BABBITT, M. Eng. So. W. Pa.—Is there some great gap between the amount of carbon and manganese or does not the one go into the other?

MR. L. C. MOORE—No, they don't. You can take plow steel stock and make cast steel rope out of it to very good advantage. But in the first place plow steel costs too much and requires too much care in the treatment. Notwithstanding the fact that there is only 2/10th% difference in possible carbon and manganese, you can't anneal it with the same frequency that you can cast steel stock.

MR. H. C. BABBITT—There would be a difference of about 25,000 lbs. tensile strength in the ingot alone.

Mr. L. C. Moore—There is another matter. Plow steel stock is much harder on the tools and it is much harder to handle for other reasons. It can be finished to run up to 250,000 lbs. tensile strength per square inch. Yet under exactly the same conditions, the same diameter of wire will stand more bends than cast steel. That is why the manufacturers to-day tell you that you can use plow steel rope on a smaller diameter sheave than you can cast steel rope; and it is a fact, because it will wear longer.

Mr. H. C. Babbitt—Suppose you were to drop your manganese on the plow steel, would it not make it better?

Mr. L. C. Moore—It would be better except in drawing the metal. If you cut down your manganese, you can draw your stock through the dies more rapidly. I might say in this connection that American manufacturers of steel never made rope stock successfully yet to my knowledge. Perhaps the fact is that they would rather pay attention to larger casts. There is only fifty tons of cast steel rope made every 24 hours in this country and that would not be a very great output for a steel plant.

Mr. F. S. Jackman—Do the American Steel and Wire Co. import all their stock?

Mr. L. C. Moore—I understand they make considerable of their stock. But I think they don't sell it to anyone else. I believe it is a fact that the largest manufacturers of rope in this country, from certain grades of rope stock they buy abroad, get 95 tons of finished rope wire out of 100 tons of stock. That stock will be so uniform by the time it is finished to say 0.83″ and similar sizes, that the tensile strength machine is hardly necessary and is used as a mere matter of form. Of the nine manufacturers of rope in this country at least eight use almost entirely foreign stock.

Engineers' Society of Western Pennsylvania.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS

The 252nd regular meeting of the Engineers' Society was called to order in the lecture room of the Society's house, 410 Penn avenue, Pittsburgh, Pa,. at 8:15 P. M., Tuesday, February 21, 1905, with President Samuel Diescher in the chair, 40 members and visitors were present.

The minutes of the last meeting were read and approved.

The report of the Board of Directors was read by the Secretary recommending for membership the following list of applicants:—

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
WILLIAM GEORGE BOYLE,	Chief Engineer, Oliver Power Plant, Forrest Avenue, Bellevue, Pa.	John A. McConnell. F. R. Dravo. Samuel Diescher.
THEODORE O. DEAUMER,	Mining Engineer, York Run Mines, R. F. D. No. 7, Smithfield, Pa.	W. E. Prindle. W. G. Wilkins. J. F. Kuntz.
HENRY L. DIXON,	President, H. L. Dixon Co., 8 Wood St., Pittsburg, Pa.	DeWayne Loomis. Daniel Ashworth. F. V. McMullen.
CHARLES FRAZINE HAMILTON,	City Engineer, Franklin, Pa. Lock Box 327, Franklin, Pa.	H. J. McKinley. E. K. Morse. Samuel Diescher.
EDGAR M. MOORE,	in business under firm name of Edgar M. Moore & Co., 914 Farmers Bank Bldg., Pittsburg, Pa. 6833 McPherson St., Pittsburg, Pa.	J. F. Kuntz. W. M. Judd. W. O. Abbott.
ANSON BURLINGAME McGREW,	Ass't. Eng'r. United States Engineers, Beaver, Pa.	J. A. Atwood. A. E. Frost. William Martin.
WALTER RACHALS,	Engineer, Julian Kennedy, Box 68, Crafton, Pa.	Julian Kennedy. Gerald E. Flanagan. Samuel Diescher.
WILLIAM E. SCUDDER,	Engineer, W. G. Wilkins Co.	W. E. Prindle. W. G. Wilkins. J. F. Kountz.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
ALBERT SMITH,	Civil & Mining Engineer, Saltsburg, Ind. Co., Pa.	Samuel Diescher. Geo. T. Barnsley. Willis Whited.

On motion the Secretary was ordered to cast the ballot of the Society electing the above applicants to membership.

PRESIDENT—I have to perform the sad duty of announcing the death of two members of the Society, which occurred some time ago, but of which we received no notice. Mr. Charles Parkin and Mr. John Miller Cunningham. Mr. Parkin was well known to me as one of our foremost crucible steel manufacturers and was connected with the Crucible Steel Company for many years. Mr. Cunningham was not personally known to me.

It will be in order to appoint committees to draw up suitable resolutions.

On motion the President was instructed to appoint two committees to prepare and present suitable resolutions on the death of these two members.

MR. G. T. BARNSLEY—The twenty-fifth anniversary banquet was held on January 28, 1905. It was the closing feature of the last year's Reception Committee's work. The consensus of opinion seems to be that the anniversary banquet was a signal success, and in order to make that a matter of history the committee has been granted the privilege by the Board of Direction of incorporating the speeches that were made on that occasion in a special number of the Proceedings, so that we will have that record to look back to when the fiftieth anniversary takes place. Naturally the two banquets will be compared.

FINANCIAL REPORT.

233 tickets at $5.00		$1,165 00
240 dinners	$ 766 25	
Decorations	100 00	
Menu cards, printing of diagrams and names of participants, and tickets	183 25	
Music	50 00	
Stenographer	20 00	
Entertainment	30 00	
Making a total of		$1,149 50
Cash on hand		$ 15 50

Mr. James M. Camp—I move that the Reception Committee be given a vote of thanks for what was undoubtedly the most successful banquet the Society ever had. Particularly for the fact they came out ahead, an unparalleled event in the last five years. And it assures the committee that the $5.00 rate will be continued.

The motion, being duly seconded and put to vote, was carried unanimously.

President—It gives me great pleasure to comply with this action and extend the thanks of the Society to the chairman and the members of the Reception Committee for the successful accomplishment of the banquet.

We will now be addressed by Mr. Howard W. DuBois, on "A Reconnaissance for the Platinum Metals in British Columbia."

After hearing and discussing the paper the meeting adjourned at 10:45 P. M.

F. V. McMullin,
Secretary.

The regular monthly meeting of the Board of Direction was held at the Society's house, 410 Penn avenue, Pittsburgh, Pa., Saturday evening, February 18th, 1905, at 8:15 P. M.

Present: Messrs. Diescher, Flanagan, Whited, Barnsley, Schatz, Johnson, Stucki, Maury, Morse, and Secretary.

The minutes of the preceding meeting were read and approved.

The following resignations were voted accepted: Orville Benson, Andrew D. Blythe, Edward P. Cooke, Frederick Haworth, H. D. Hershey, W. C. Siebert, V. E. Sisson, Jas. E. Tatnall, W. C. Temple.

A request from the Cummings Filter Co., for permission to republish an article by the late R. N. Clarke, on the "Use of Boneblack in Domestic Filters," and published in the proceedings for February, 1893, was granted, with the stipulation that credit be given the author and the Society.

On motion the Secretary was ordered to comply with the request of Il. Cemento, of Genova, Italy, and forward them a specimen copy of our Proceedings with the end in view of placing the same on our Exchange list.

On motion the chairmen of the Programme Committee and of the Structural Section were authorized to incur the necessary expense in order to secure the proper kind of a lantern for their respective meetings.

On motion the House Committee was ordered to take steps to secure the proper kind of a lantern.

On motion the Reception Committee was authorized to print the speeches at the 25th anniversary banquet in a special number of the Proceedings.

On motion the Secretary was ordered to take steps to collect the dues from the delinquent members.

On motion the Secretary was voted a salary of $1,200.00 a year, and he was authorized to pay an assistant $10.00 per week.

On motion the meeting adjourned at 11:30 P. M.

F. V. McMullin,
Secretary.

CHEMICAL SECTION.

The regular monthly meeting was held Thursday evening, February 23, 1905, at the Society's house, 410 Penn avenue, Chairman George P. Maury, presiding, and twenty-six members and visitors being present.

The Chairman announced the following committee appointments for the year:

Programme—J. M. Camp, chairman; C. R. Rich, R. L. Frink.

Chemical Literature—J. A. Mohr, chairman; G. O. Loeffler, Philo Kemery, N. H. Finley, W. E. Dickson.

Methods—A. G. McKenna, chairman; H. E. Walters, J. O. Handy.

The paper of the evening was read: "Some Experiments on the Determination of Antimony in Alloys," By Harry Edward Walters. After a discussion by Messrs. J. O. Handy, C. H. Rich, F. C. Phillips, J. E. Babb and H. C. Babbitt, the Chair, on motion of Mr. H. C. Beggs, appointed the following committee to investigate methods for the estimation of antimony in the presence of tin: J. C. Phillips, J. O. Handy, J. E. Babb, G. D. Chamberlain, C. H. Rich.

At 9:45 the section on motion adjourned.

HARRISON W. CRAVER,
Secretary.

MECHANICAL SECTION.

The regular monthly meeting was held at 410 Penn avenue, February 7th, 1905, at 8:15 P. M. Chairman H. H. Anderson in the chair, 55 members and visitors present.

The minutes of the preceding meeting were read and approved.

A paper was read by Mr. G. L. Luetscher, on "Open-Hearth Furnaces." The paper was discussed by Messrs. Ralph Crooker, Jr., H. C. Babbitt, A. Stucki, R. A. McDonald, G. E. Flanagan, Samuel Diescher, L. C. Moore and H. H. Anderson.

On motion a vote of thanks was extended to the author of the paper.

On motion the meeting adjourned at 10:30 P. M.

H. D. JAMES,
Secretary.

STRUCTURAL SECTION.

The regular monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held in the Society's house, 410 Penn avenue, Tuesday evening, February 28, 1905.

Meeting called to order by Chairman E. K. Morse at 8:15 P. M., 45 members and visitors present.

Minutes of last monthly meeting read and approved.

Chairman Morse then introduced the speaker of the evening, Mr. O. W. Price, Associate Forester, National Bureau of Forestry, Washington, D. C., who delivered an illustrated lecture on Forestry.

The discussion was entered into by the following members: Messrs. Samuel Diescher, Thos. H. Johnson, H. J. Lewis, Morse, Swensson, Crooker, Whited, Stucki, Irvine, Schellenberg, and the lecturer, Mr. Price.

After the discussion a vote of thanks was tendered Mr. Price.

There being no further business, on motion section adjourned at 10:25 P. M.

T. J. Wilkerson,
Secretary.

FLOW OF WATER THROUGH PIPES FED BY RESERVOIRS.*

BY SAMUEL DIESCHER.

Member Engineers' Society of Western Pennsylvania.

The determination of formulas by which the flow of water through pipes under various heads may be calculated, has engaged many minds and has cost much hard labor without, however, attaining any satisfactory results. All of the formulas developed are complicated and unwieldy, some of them very much so, and all assume one or more data as a basis to build upon. According to some the resistance grows with the square of the velocity and the square root of the cube of the velocity; others find that it grows with the fifth power of the velocity and, again, some say it grows with the seventh root of the twelfth power of the velocity.

If a jet of water issues from an opening immediately in the bottom of a tank, its velocity is not as great as if a piece of pipe were so attached and fitted to that opening so that the outflow had to descend through that pipe.

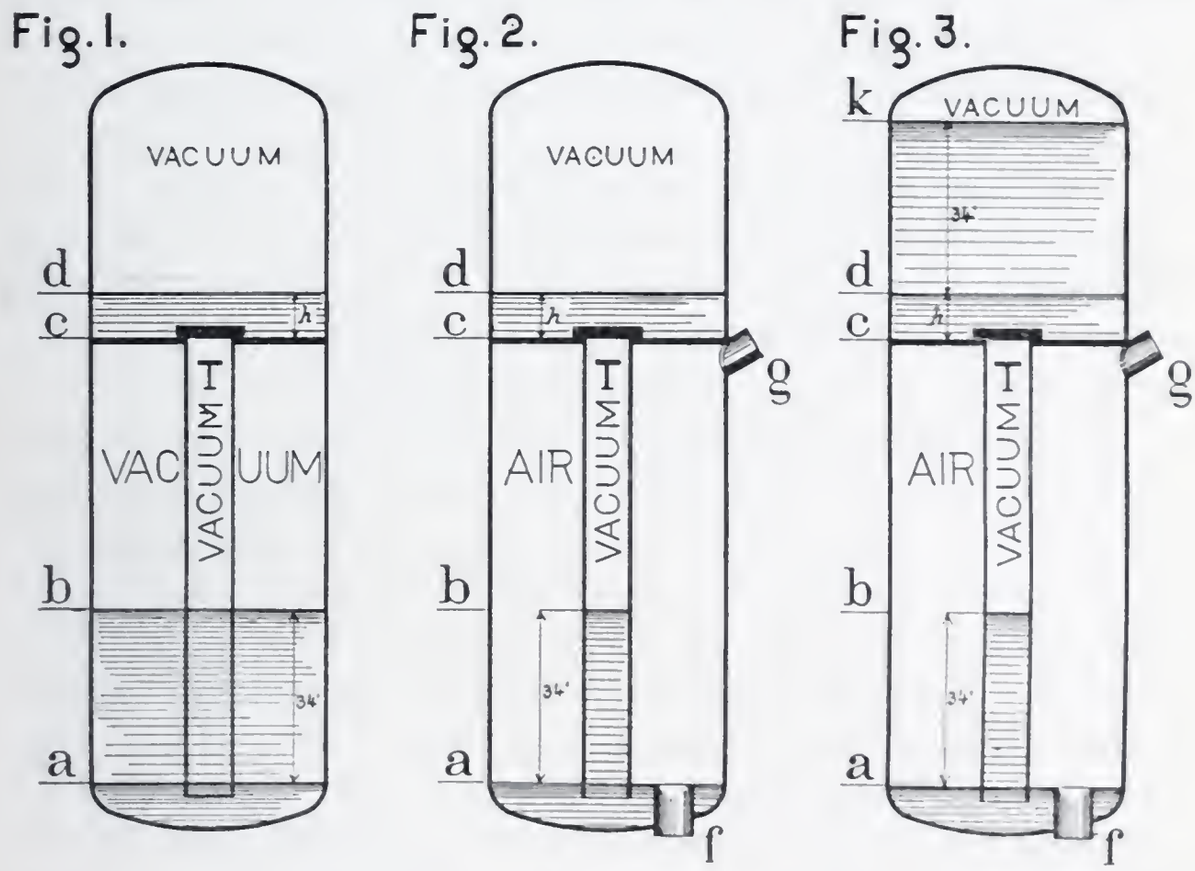
Why is this?

We know for certain that all objects on the earth are subjected to a pressure exerted by the weight of the atmosphere. In accord with this, if there is anywhere an inclosed space not occupied by air or any other substance, air by reason of being under pressure will rush into it if given a chance, until the pressure of the air within that space is the same as without it. And if air finds no direct access to such space, due, for instance, to the intervention of a body of water, then by reason of the pressure the atmosphere exerts upon the surface of that water, this latter is forced into the void and continues to flow in until either that space is fully occupied or that the water rises therein to a height at

*Read at meeting of the Society, January 17, 1905.

which action and reaction between air and water are in equilibrium. This performance is what is meant in practice by the term "Suction."

The apparatus shown in Fig. 1, of the drawings is a cylindric vessel similar to a boiler, set on its end. It may be of any diameter from a couple of feet upwards, but it is necessary for our purpose to assume that it is from eighty to a hundred feet in height. Above half the height a diaphragm is inserted and tightly fitted to the shell. At about the center of this diaphragm



is a hole and coincident therewith a tube is attached to the diaphragm, that extends almost to the bottom of the vessel.

By reason of said diaphragm the space in the vessel is divided into two chambers of unequal capacities. The opening above the tube is covered by a disc that may be removed if so desired, but if put in place it fits tight to its seat.

The lower chamber is filled with water to the line b b; the rest of the space is a vacuum.

The upper chamber contains water up to d d; here also the rest of the space is a vacuum.

Within the central tube T the water is of the same height as that surrounding the tube; the space from water line to cover D is a vacuum.

If we slightly move cover D, water will drop into the tube. If the lower end of this tube were closed the admission of water would cause a rise in the tube, but as it is open, any tendency toward accumulation there disturbs the equilibrium between the water within and without that tube, whereupon equalization of pressures begins and results in re-establishing a uniform level inside and outside of the tube T. This action continues also if the opening under the cover D is increased to the full size of the tube. The down flow from the upper chamber and consequent equalization will under all circumstances act in harmony.

According to Fig. 1, the water in the lower chamber reaches to the line b b, which is 34 feet higher than line a a. This height of 34 feet is purposely selected, as it is the elevation to which at sea level water is forced by the atmospheric pressure, if the space entered by the water is a perfect vacuum.

The pressure of the atmosphere at sea level is generally assumed to be 14.75 pounds per square inch. This divided by 0.434, the weight in pounds of a column of water of one square inch cross section and 12 inches length, gives 34 feet in whole figures. Consequently the pressure that a column of water 34 feet in height exerts upon its base, equals that of the atmosphere at sea level. Therefore, if we take a long tube of any diameter, provided with a piston placed at one end of the tube and put that end into water while the tube is held perpendicular, then on withdrawing the piston, the water will follow it until it has risen to a point 34 feet above the water in the source. But if the piston keeps on rising beyond the 34-foot level, the water will not follow, but the space between that level and the lower face of the piston will be a vacuum, no matter how much further that piston may eventually travel. We see then, that the height of the column of water within that tube is limited by the sustaining power of the atmosphere.

In the experiment shown in Fig. 1, all water coming from the upper chamber had to escape from the tube against the opposition of the outer body of water of 34 feet depth, and the

pressure it thus encountered is the same as that of the atmosphere. Now we repeat that experiment but with the difference that we substitute the atmosphere for the 34-foot body of water. For this end two openings are provided, one marked g, below, and close to, the diaphragm, and another f, through the bottom of the vessel, Fig. 2. At the lower opening a short tube is inserted of which the upper end reaches to the line a a. As soon as in this manner communication between the atmosphere and the chamber is established, air rushes through opening g into the space formerly a vacuum, and simultaneously water flows off through the tube f. This action continues until the water level has sunk to the line a a and the air pressure within the chamber equals that in the open atmosphere.

By reason of the atmospheric pressure being equal that of a column of water 34 feet in height, the water within the tube T is not in the least affected by the change just made, and if now we again let water from the upper chamber flow into this tube, we shall find that it will escape around the lower end of the tube precisely in the same manner and against the same resistance when emerging into the air, as it did before, when it encountered the pressure from the 34-foot column of water.

If under the present conditions the opening at cover D is being gradually increased, the thickness of the jet of water will increase accordingly; however, this cannot affect the column of water in the tube, because the surplus so admitted escapes at the foot of the tube and eventually through outlet f. There is not the slightest reason to assume that by a further increase of opening, or for that matter the entire removal of cover D, the atmosphere will cease to sustain that column of water in the tube. The impression made on the observer that by a rush of water through the tube the action of the atmospheric pressure is being destroyed, is wrong. That column was set in motion immediately upon the intrusion of the first quantity of water, no matter how insignificant that may have been, for any load imposed upon that column causes the escape below of a quantity of water equal in weight to that introduced above. This displacement of water at the lower end of the column can take place only by a bodily downward movement of the whole column,

and a faster supply of water is necessarily followed by an equally fast downward movement of the column, but under all conditions that prevail at this stage of the experiment, the length of the column remains the same, and all water escaping below does so against the pressure of the atmosphere.

During the flow of water through the tube T, the column is in constant motion, and while in this condition, it loses in length at the lower end at the rate it gains at the upper.

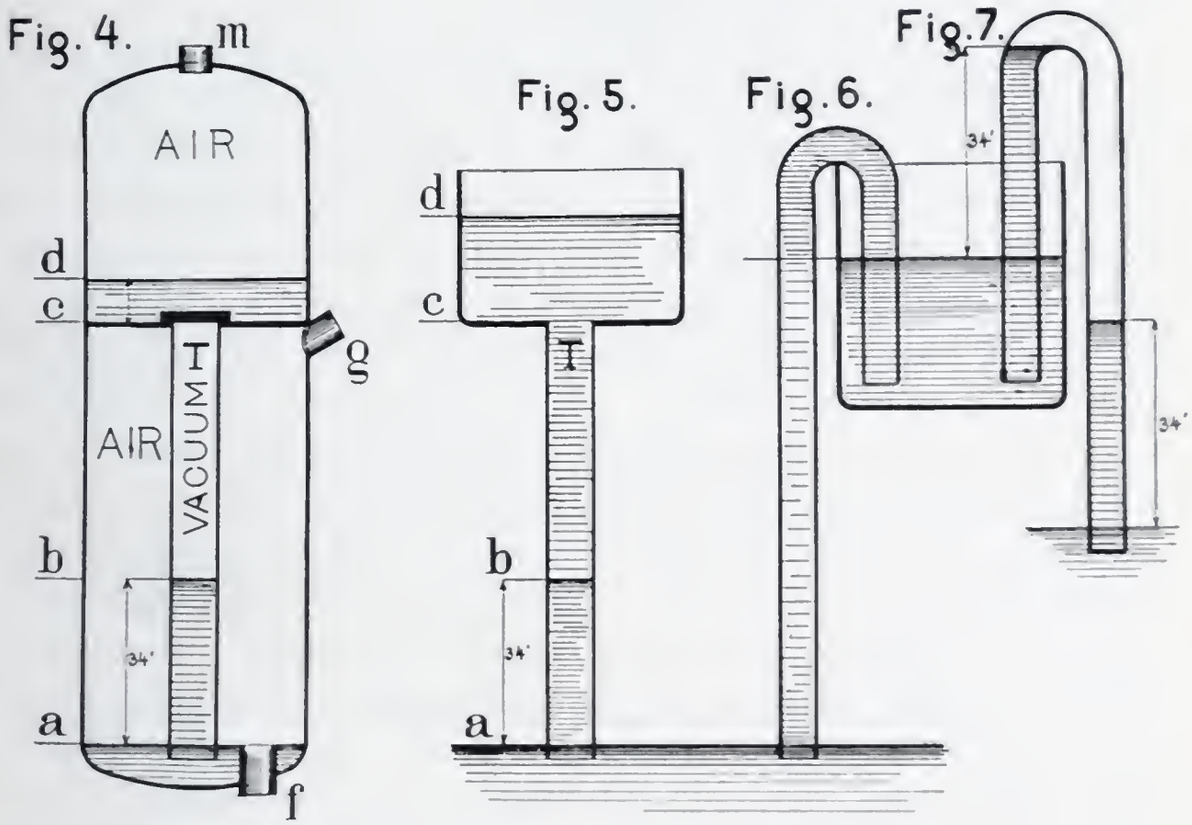
In the preceding two experiments the space above the water level on line d d, in upper chamber, was a vacuum and it continues so. Now, let us assume that in some manner we succeed in filling that chamber with water to the line e e, Fig. 3, which is 34 feet above line d d, and that we can maintain it there at our will. In doing so a load of 14.75 pounds per square inch is added to that of the water already in. This additional load is equal to the pressure of the atmosphere, and though the space above the new water level is still a vacuum, yet the effect is precisely the same as that of the atmosphere.

If now with this increased load of water the former experiment is repeated, and supposing that cover D is being moved and the hole gradually increased to the full opening of the tube, it will be found also that in this case, as in the preceding ones, the column of water will be maintained just the same as if no change had been made in the upper chamber. But we also notice that the head of the water above the entrance to the tube T grew by 34 feet, whence it follows that the impulse the water received at the point of entrance has increased equally with the head of the water in upper chamber.

In the experiment in Fig. 4, we let the water from the upper chamber run out until its surface is brought back to the line d d, where it was during first and second stages. When this is reached we admit air into the upper chamber through an opening, m, made in the head of the vessel. Again we understand that we have arranged to furnish a continuous supply of water by which the water level at line d d will be maintained to the end of the experiment. These provisions being made, we gradually move cover D, until the opening is as large as the tube itself. Since this case is in every essential identical with that illustrated in

Fig. 3, it follows that the results thereby attained must also be identical with those in the former case.

The fact that in the one instance there was 34 feet of water employed to produce a pressure upon the original body of water in upper chamber, and now it is atmospheric pressure we use, does not affect matters at all, for in both cases the pressure is 14.75 pounds per square inch upon the area of the body of water in the chamber.



An essential feature demonstrated by this series of experiments as far as now carried out is: That the 34 feet of head at the foot of the tube is entirely neutralized by the atmospheric pressure opposing the discharge at the foot of the tube, and that the quantity of water entering the pipe depends entirely upon the impulse it receives within a reservoir; and that the head producing that impulse depends upon the head of the water in the reservoir plus the atmosphere's unbalanced pressure upon the surface of that body of water.

The experiment of Fig. 4 is identical with that of Fig. 5, which is a practical existing case, for as air has free access to both chambers, it is entirely unnecessary that this experiment

be made within an inclosed space; the conditions are the same as with an open basin from which a pipe is receiving and conducting water.

Figures 6 and 7 represent two syphons. That shown in Fig. 6 is in action. To start such a syphon, it is necessary that it shall first be filled with water in such a manner that all air will be driven out, whereupon the flow will begin and continue until the water in the tank has sunk to the point where air gets access to the receiving end of the device.

In the state as shown on the drawing, the water rises in the receiving branch to the apex, then down on the other side until discharged. To set this apparatus in action it needs to be filled only once, and then it goes on with its work until either the device is destroyed or the supply in the tank is exhausted. We may ask here, why is it that by this device a large quantity of water is continuously being lifted, sometimes even to a considerable height, without any apparent effort? The fact in this case is, that the energy required to do this work was stored in the water in the tank as that tank was being filled. For it took effort to get that water into that tank, no matter whether it was accomplished by manual or mechanical work. The water in the tank possesses potential energy, by reason of its situation above the level at which it is being discharged from the syphon. The energy contained in that water is the product of its entire weight into the height above the point of discharge. A syphon can act only if the vertical fall of the branch on the discharging side exceeds the vertical rise on the receiving side. When this condition is fulfilled then the load on the descending side is greater than the resistance on the rising side. This resistance consists of the weight of the rising column of water, the inertia of it, and the friction within the tube. The smallest excess of energy over these combined resistances will induce motion, and the velocity of it increases like that of freely falling bodies, with the square root of the fall in the discharging branch. However, there is a limit to this; for since the rising flow is produced by the atmospheric pressure upon the surface of the water in the tank, it is obvious that this limit is at the height up to which a column of water is sustained by the atmosphere. Moreover, as the weight of

the rising column, the friction in the rising branch, and the inertia of the water must be overcome by the atmospheric pressure; therefore, a flow over the apex, or water shed, can take place only if that point lies somewhat below the height of the barometric column of water of the locality where this syphon is being employed.

The water contained in both branches of the syphon, Fig. 6, from the level of the tank to the apex, and down on the other side to the same level, is in equilibrium. The column on the rising side is sustained by the atmospheric pressure bearing upon the water in the tank. Motion is induced only if on one side the column is somewhat longer than on the other. If the descending branch were to enter water of the same level as in the tank there would be no motion; or if that branch were sawed off at that point and its end closed with merely a sheet of paper, the water in that branch would be held in suspense for any length of time.

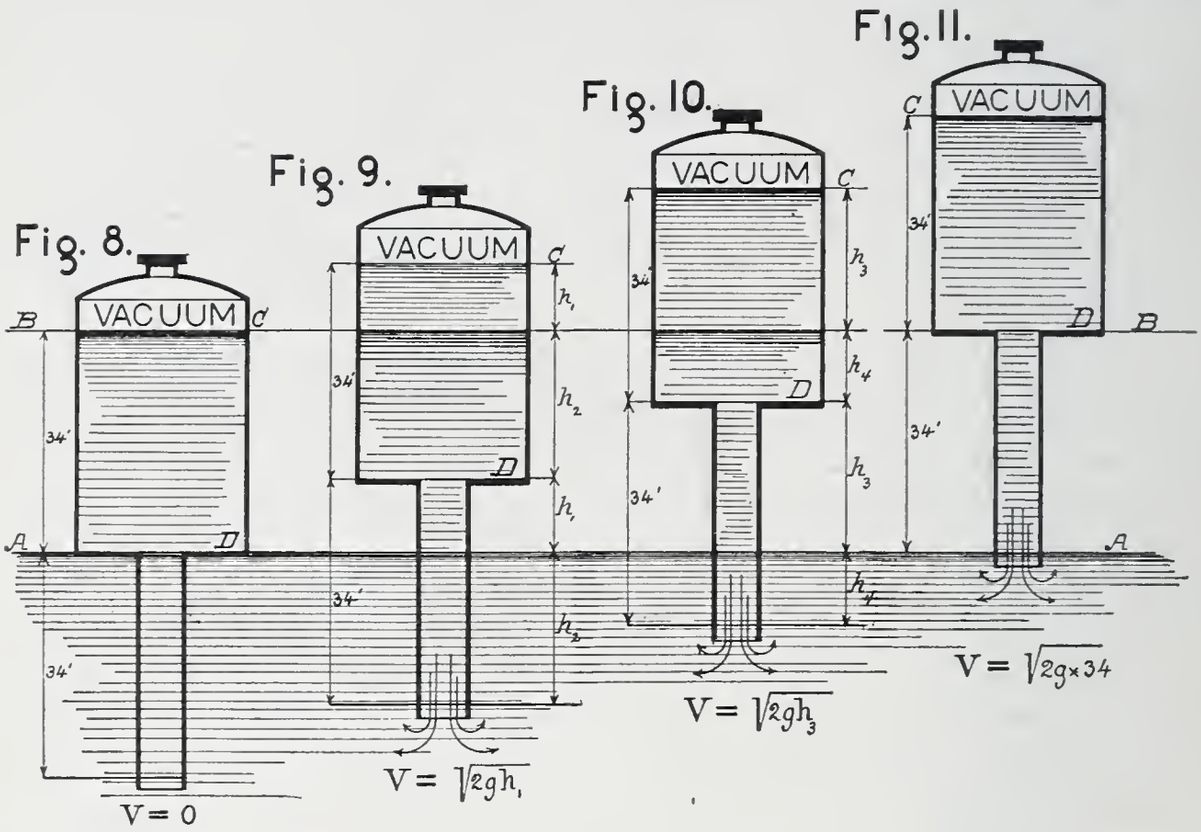
The atmosphere's action is induced in the manner that the column on the descending side exceeds in weight that on the rising side, and an excess of weight over all resistance is what neutralizes, either partly or entirely, the atmospheric pressure that would otherwise prevent the discharge of the water. The extent to which this neutralization occurs depends entirely upon the magnitude of that excess. But here again a limit is set to the effect of the descending column, in as much as any excess in fall over the barometric column, plus resistance head, has no influence upon the rising side of the device. However, if there is a surplus of energy in the fall, beyond that required to bring the water over the apex, that energy may be utilized if employed in driving some hydraulic motor, provided that the quantity is sufficiently large to justify the installation.

The conditions under which the atmospheric pressure opposing the outflow is partly or entirely neutralized, will be shown further on.

Fig. 7 shows a syphon by which the supply has been drawn upon until the column on the rising side reached the barometric height, at which action ceased. We see in this figure, that although the fall on the discharging side is considerably more than

the barometric column of water, yet motion stopped for the simple reason that at that elevation the atmospheric pressure is in equilibrium with the column on the rising side.

What this experiment with the syphon is intended to demonstrate is: "That if water flows through a pipe fed from an elevated source and the pipe has a fall equal, less or more than, the barometric column of water, then the impulse the water receives at the point of entrance to the pipe, is due not merely to the head of the water in the reservoir, but also to the atmospheric pressure bearing upon the surface of the water, which



pressure may vary according to the prevailing condition in any given case, but it reaches its maximum when that fall is equal to the local barometric column."

We shall now further investigate the impelling effect of the atmospheric pressure on water entering a pipe, and in the pursuance of this, we use an apparatus consisting of a cylindric vessel closed at both ends, and about 40 feet in length. The diameter is of no particular moment, just so it is large enough for our purpose. To the bottom of this vessel is attached a tube of about 35-foot length.

On the drawing before us, this device is shown in a series of four positions, each differing from the preceding one, by the height at which it is situated with reference to the horizontal line marked A A. This line represents the surface of a body of water, for example, a pond, or reservoir, of considerable depth.

It is to be understood that provision is made that the vessel may be filled with water to any point desired, so that any stage of water can under all conditions be maintained therein.

At the beginning the valve in the head of the vessel, Fig. 8, is opened and the vessel is sunk until entirely submerged, filled with water, and all air is expelled from it; then the valve is tightly closed and the vessel lifted until its bottom D comes even with the line A A, which is the level of the water in the pond. When lifting, the apex of the vessel reaches the height B B, water begins to escape through the tube and continues so until the vessel has come to rest, when the height of the water within becomes stationary at the level B B, and the space above that line is a vacuum. The line B B is 34 feet above the surface of the water in the pond, and therefore in weight equal to a column of the atmosphere of same base area.

If we imagine the opening at the foot of the pipe closed, so that the pressure from the atmosphere without is rendered ineffective upon the body of water in the vessel, then we may presume that body to represent the pressure of the open atmosphere, for it bears upon the bottom of the vessel with the same intensity as is exerted by the atmosphere at sea level. But if that cover is removed from the foot of the tube, immediately an upward counter pressure comes into action, equaling that exerted by the water in the vessel. Owing to the equality of these opposing pressures, no motion in either direction takes place, because the forces engaged are in equilibrium, otherwise the water in the vessel would escape through the tube, until its level sank to line A A.

At the next step, we lift the vessel the height h_1, as shown in Fig. 9, and immediately the water level in the chamber sinks to the line B where it comes to rest again, because up to that height it is sustained by the atmospheric pressure. But since we have made provision to refill the vessel and also to maintain the

water at whatever level we choose, we avail ourselves of this means and restore the water to the line C and keep it there, notwithstanding the continuous discharge at the foot of the tube. At this juncture we have again two opposing forces in action, namely: the one from below, due to the atmospheric pressure upon the surface of the pond, and the other downward, exercised by the weight of the 34-foot column of water in the chamber. But having lifted the vessel the distance h_1, the whole column of water measured from A to C is not 34 feet, but $34'+h_1$; and since the upward thrust ends at the height of 34 feet from level A, therefore, there is a downward, unbalanced force in action equal to the weight of a column of water of the height h_1; and to this excess of force is due the discharge of water from the lower end of the tube, and the velocity at which that outflow takes place is $\sqrt{2gh_1}$.

What we observe in Fig. 9, occurs also in Fig. 10, with this difference, however, that in this latter instance the vessel is lifted a greater height than in Fig. 9, and for this reason the impulse that causes the discharge through the tube, is correspondingly greater, too. Thus the velocity now is $\sqrt{2gh_3}$.

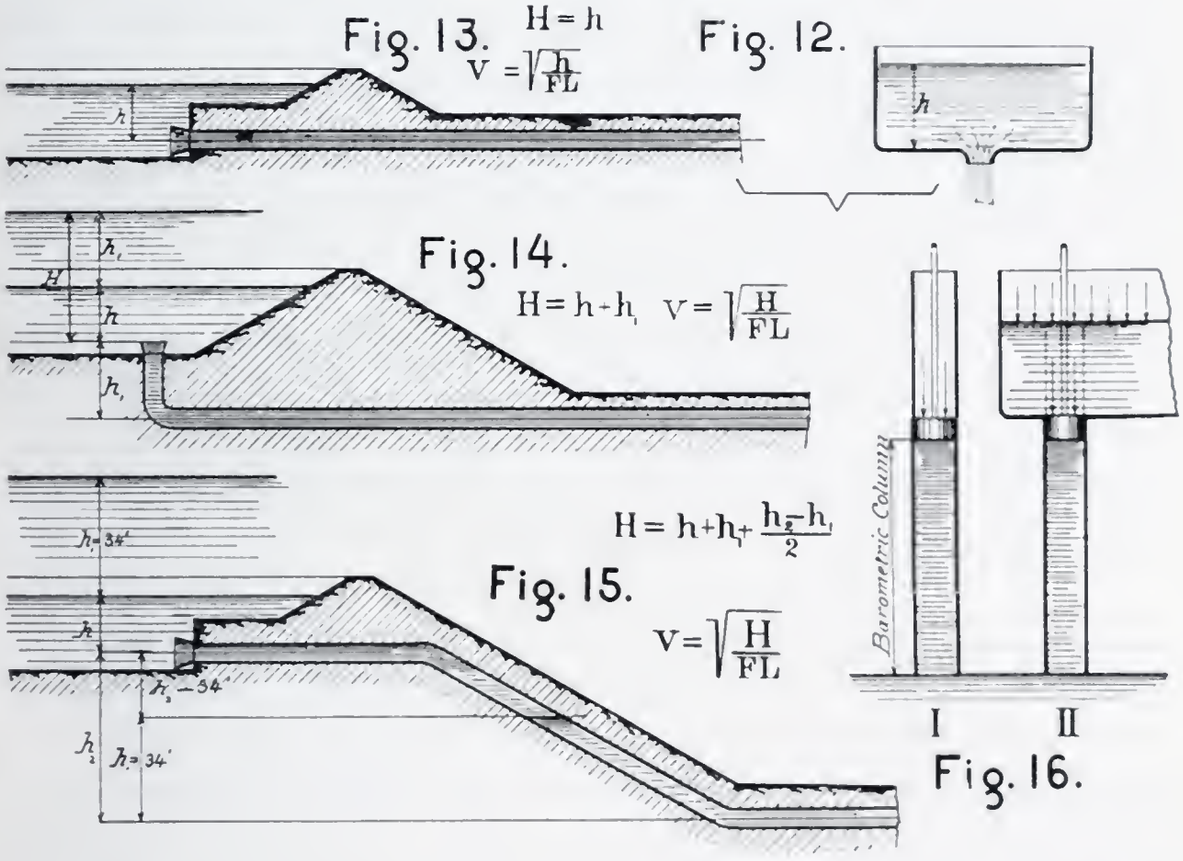
In Fig. 11 we see the vessel lifted 34 feet, that is, the entire height of the column that the atmosphere is able to sustain, and as this brings the level of the water in the chamber to twice 34 feet, and since any balancing of opposing forces can occur only within the 34 feet from line A A up, therefore, the whole column contained in the chamber is now active in expelling water from the tube, and the velocity at which this expulsion takes place is $\sqrt{2g\times34}$.

Considering the results obtained by these four experiments, we see that if the vertical distance from the discharge to the receiving end of the pipe is 34 feet then the impulse causing the outflow is at its maximum, and if that distance is less than 34 feet, then the impulse is also less and in accord with that distance. This holds good also if the distance is zero, as in Fig. 8, in that instance the impulse, too, is equal zero.

It is to be understood that the theoretical discharging end of the tube is not at the depth below the water level where

according to the drawing it is shown to end, but on the line A A, for the piece of tube extending beneath the surface of the pond has no effect on the results of the experiments.

Lifting the vessel more than 34 feet would not affect the results in either direction, because what we consider here is the effect of the two opposing pressures of the atmosphere. Were we, for example, to lift the vessel, say, 100 feet, then the space between the top of the atmospheric water column in the tube and the receiving end of the latter would be filled out with water which would act like a rod of that length.



We represent the atmosphere's pressure in the chamber by a column of water, because this is the most comprehensive form in which the demonstration of the theory can be made.

In the last four experiments we do not consider the body of water that is always present in reservoirs when in service, although in the end the results of our investigations would be the same. The reason for this omission is that introducing that additional body would only have complicated matters, without any gain in clearness.

In Fig. 16, we see an upright tube marked I. This tube is provided with a piston and a rod by which it may be withdrawn. The lower end of the tube is in water. At the beginning of this experiment the piston is in its lower position, so that there is no air in the tube below the piston. If we lift the piston in the tube, to the height shown, the water from the pool follows the piston in its ascent. When that height is reached the atmosphere exerts a pressure upon the piston equaling the weight of the column of water beneath it. And if we release the rod, the piston will immediately descend to its former position.

The reason of this phenomenon is, that when lifting the piston we did so against the pressure of the atmosphere bearing upon its upper surface. This pressure as we know is in one and the same altitude constant for all practical purposes. Thus, as we began lifting, every square inch of the piston's area was subjected to a pressure of 14.75 pounds; however, the moment that ascent began, we removed the pressure from the water under the piston, and as the water in the pool or whatever that source may be, is under the same pressure as the top of the piston and, furthermore, since pressure upon a liquid extends in every direction, the water immediately followed the motion of that piston. When the rise begins the pressure from beneath is the same as that bearing upon the surface of the pond but with the growth of the column behind the piston, its weight grows also, and as the pressure of the atmosphere remains the same, it is evident that the sustaining capacity of the latter decreases with the growth of the column that gains in weight as it gets longer. Thus gradually the column in the tube reacts more and more upon the pressure from below, until when the piston has traveled the length of the barometric column, the weight of that column will just be what the pressure of the atmosphere can sustain and there is equilibrium. When the piston arrived at the height of that column, the upward pressure within the tube ceased entirely, and consequently did not assist lifting by neutralizing any portion of the atmospheric pressure upon the piston. On the other hand, the column having now reached its greatest height exercises its full weight against the atmospheric pressure at the foot of the tube, and since those forces are equal, there is equilibrium within the tube.

When the piston rises beyond the barometric height, the work performed from there on becomes constant and a maximum, whereas in the beginning of the movement it was at its minimum.

If the piston is released from the power that raised it, it will immediately move downward, starting under a pressure of 14.75 pounds per square inch, and loosing pressure in proportion to the decrease in the height of its column, until it reaches the minimum at the level of the pool.

The piston in II is subject to exactly the same resistance from the atmosphere as the former, but as it is connected with a tank filled with water, it is plain it has to bear also the weight of the column of water in the tank. Hence, the ascent of this piston is resisted by the sum of two forces, namely, the weight of the water in the tank, and that of the atmosphere bearing upon that water. This demonstrates conclusively that if water flows through a pipe with a fall, either the whole or a part of the column in that pipe, is held in equilibrium by the air at the point of efflux. On the other hand, a pressure by the atmosphere equaling the weight of the column balanced at the efflux, is bearing upon the water in the tank. Therefore, in those cases where the fall in the pipe does not exceed the height of the barometric column, it is of no consequence whether we take cognizance of the transposition of effects or not.

What we observed here now, applies also to the effect of the atmospheric pressure upon the water in a reservoir, namely:

If in a pipe connected with a reservoir, as shown in Fig. 14, the vertical distance h_1, from the receiving to the discharging end, is either less than, or equal to, the height of the local barometric column, then the water contained in that pipe acts with its full weight against the opposition of the atmosphere to the discharge of the water.

On the other hand, to whatever extent the atmosphere's opposition to the discharge of the water may be counteracted, the resistance to the entrance of the water at the receiving end will be reduced to precisely the same extent. In other words the effect that the atmospheric pressure exercises upon the water in the reservoir is equal to the effect of the barometric (or shorter) column in the pipe against the atmosphere's opposition to the

discharge. Since the barometric column in the pipe is counterbalanced by the atmosphere opposing the discharge and thus rendered ineffective, while the effect of the atmosphere's pressure upon the water in the reservoir is to the same degree increased, therefore, in calculating the conducting capacity of a pipe in connection with the head, we must deduct this column from the head in the pipe and add it to the head in the reservoir.

If a pipe conducting water from a reservoir is level, as in Fig. 13, hence without any fall whatever, the pressure of the atmosphere bearing upon the water in the reservoir and that opposing the discharge at the end of the pipe, are in equilibrium and there occurs no transposition of heads.

If the reservoir is a tank, Fig. 12, with only a hole in the bottom from which the water issues, then, in that case, too, equilibrium prevails so far as the effect from the atmosphere is concerned.

In the case of Fig. 15, there are three heads to take into the calculation. First the head of the water in the reservoir; second the barometric head in co-operation with the former; and third the remaining head in the pipe. This latter head comes to action only within the pipe, in as much as it helps in overcoming the friction in the pipe. The former two heads come to action at the entrance to the pipe with the full effect of their combined pressures. At that point the effect of the pipe head is nil, but it grows, and reaches its greatest intensity where it adjoins the barometric column. In determining the velocity of the flow it is necessary that we first ascertain the total pressure we may count upon. The combined pressures from the reservoir head and barometric column are in every case directly ascertained, but that in the pipe is not uniform, but grows from nothing to a maximum; therefore, we have to take its average, which is half its maximum. But in as much as the pressures are always in proportion to the heads and even the resistance manifests itself in units of heads, it is most convenient to take the heads instead of the corresponding pressures.

Thus, referring to Fig. 15, if h be the head in the reservoir, h_1 the barometric head; h_2 the entire pipe head; and H the sum of all effective heads, then we get:

$H = h + h_1 + \frac{(h_2 - h_1)}{2}$

In view of the foregoing demonstrations of what is going on during the flow of water through pipes, it is evident that unless the head is divided according as each of its parts comes to action, and is so applied in the calculation, correct results cannot be produced.

The fact that a decided change in effect occurs at the point where the head in the pipe exceeds the barometric column, accounts for most of the trouble heretofore encountered in developing a correct formula.

The deduction drawn from experiments, that the resistance to the flow does not grow with the mere square of the velocity, but according to a higher power, and as some think, to a much higher power, is due entirely to the sudden change in effect as the head in the pipe exceeds the barometric column. And that the various investigators have not come to an agreement as to what that power is, comes entirely from the circumstance that in their experiments they have each dealt with pipes of different heads.

According to the formula herein presented, the velocity v is equal $\sqrt{\frac{H}{FL}}$. But much depends on the composition of that head, H.

If there is no fall in the pipe, then H is simply the depth of the water in the reservoir.

$H = h.$

If there is a fall, but it does not exceed the barometric column of water, then H is composed of the depth of the water in the reservoir and the fall in the pipe.

$H = h + h_1.$

Finally, if the fall in the pipe is more than the barometric column, then the effective head H is composed of:

The depth of the water in reservoir, plus the barometric column, plus the entire pipe head minus the barometric column, divided by two.

Thus: $H = h + h_1 + H + h = h_1 \frac{(h_2 - h_1)}{}.$

To show what this may amount to, let us consider two cases with widely different heads.

For example, we have a case in which the depth in the reservoir is 30 feet, and the fall in the pipe is 40 feet. According to the aforesaid, H will be $30+34+\frac{6}{2}=67$ feet, and as the total nominal head is $30+40=70$ feet, the difference between the nominal and the effective head is only 3 feet.

Now let us consider a head as it occurs in and around Pittsburg, say, 500 feet.

In this instance the effective head is, if assuming 30 feet in reservoir: $30'+34'+\frac{(500-64)}{2}=64+218=282$ ft. The difference between this and the nominal head is, therefore, $500-282=218$ feet. Is it to be wondered at if the investigators arrived at the conclusion that the resistance grows according to some higher power, the magnitude of which has so far not been possible to determine?

In Fannings book on Hydraulic Engineering, etc., there is in Table 63, page 254, given a problem and solved according to 17 formulas by 13 known authorities. The data given is:

Diameter of pipe, 12 inches.

Length of pipe, 10,000 ft.

Head, 100 ft.

For the purpose of comparison, let us solve that problem by the formula presented in this paper. But since the characteristic feature of this formula is that the head be divided into three parts, namely: the head in the reservoir, the barometric column of water and the mean effective head in the pipe, and as we do not know what reservoir head to use, so to cover some range of latitude we make three calculations, each with another head in reservoir, and corresponding pipe head, the sum of which always makes 100 feet.

The friction head F is taken from "Weston's Friction of Water in Pipes." For a 12-inch diameter cast iron pipe of 1,000 feet length, at a velocity of one foot per second, this friction head is 0.33 feet. Since this coefficient is for 1,000 feet of pipe, the length of 10,000 feet given above, enters the calculation as $L=10$, and $FL=3.3$.

"A." For 30 feet of water in reservoir, and a pipe head of 70 feet:

$$H=30+34+\frac{(70-34)}{2}.$$

$H=82.$

and $v=\sqrt{\frac{82}{3.3}}=\sqrt{25},$

hence, $v=5.00$ ft. per second.

"B." For 20 ft. of water and 80 ft. of pipe head:

$H=20+34+\frac{(80-34)}{2}.$

$H=77.$

and $v=\sqrt{\frac{77}{3.3}}=\sqrt{23.33},$

hence, $v=4.83$ ft. per second.

"C." For 10 ft. of water and 90 ft. of pipe head:

$H=10+34+\frac{(90-34)}{2}.$

$H=72.$

and $v=\sqrt{\frac{72}{3.3}}=\sqrt{21.8}.$

hence, $v=4.67$ ft. per second.

We see here that all three of these results fall within the extremes of those calculated by the highly complicated formulas in the table referred to.

Table No. 63, page 254. "Results given by various formulas for flow of water in smooth pipes, under pressure, compared."

Data—To find velocity:

Given $\begin{cases} \text{H, head}=100 \text{ feet.} \\ \text{d, diameter}=12 \text{ inches.} \\ \text{L. length}=10{,}000 \text{ feet.} \end{cases}$

Fannings' Work on Hydraulics, 13th Edition.

	V = velocity in feet per second.
Equation No. 12	5.392
Chezy	5.000
Du Buat	3.978
Prony (a)	4.770
Prony (b)	4.842
Eytelwein (a)	5.280
Eytelwein (b)	4.985
Saint Vennant	4.502
D'Aubuisson (a)	4.800

Neville (b)	5.507
Neville (a)	4.780
Blackwell	4,791
D'Arcy	5.464
Leslie	5.000
Hawksley	4.804
Jackson	5.000

Results attained by using formula:

$$v=\sqrt{\frac{H}{FL}}=\sqrt{\frac{h+h_1+\frac{h_2-h_1}{2}}{FL}}$$

For a head in reservoir 30 ft. high.....V=5 ft. per second
For a head in reservoir 20 ft. high.....V=4.83 ft. per second
For a head in reservoir 10 ft. high.....V=4.67 ft. per second

The conclusions arrived at based upon the points presented in this paper are:

1. If there is a head in a pipe, equal, more or less than, the barometric column of water, then as much of that head as is lying within the barometric column of water, is rendered ineffective by the atmospheric pressure opposing the efflux of the water from that pipe.

2. If that head exceeds the barometric column, it is rendered ineffective to the extent of the barometric column, but the rest of it is active in moving the water through the pipe, against the resistance from friction and impediments, to the extent of its effective pressure which equals that of a column of water half as high as the remainder of the head.

3. If by reason of the atmospheric opposition to the efflux, any part of the barometric column, or the whole of it, is rendered ineffective, because counterbalanced, then the water in the reservoir, as it enters the pipe, meets precisely that much less resistance as was neutralized by the barometric head at the efflux. Consequently, the atmosphere bearing continuously upon the water in the reservoir, augments the impulse that imparts motion to the water, to the same extent to which the head in the pipe is neutralized by the resistance of the atmosphere against the efflux.

4. As far as the law of resistance is known, resistance grows with the square of the velocity at which it is being overcome.

This is not only known from experience but it can also be proved theoretically. There is so far no reliable proof furnished that the resistance water encounters in its flow, is an exception to the rule. Therefore, the inference is justified that, the hypothesis that in the case of water, resistance grows at a higher than quadratic ratio to the velocity, is based upon wrong premises.

DISCUSSION.

Mr. A. Stucki, M. Eng. So. W. Pa.—I think Mr Diescher is right when he states that it is a matter of weight, which explains why only one-half of the head of the pipe above the barometric column should be taken into account. But why not take only one-half the height in the reservoir also?

Mr. Samuel Diescher—The reason why half the head is not taken of the water in the reservoir is, First: because that head and the barometric column above it attain their greatest effect at the point of entrance to the pipe and begin to work with that maximum pressure, whereas the pipe head begins at that point without any effect, but gains as its depth increases. Second: the present investigation relates only to what occurs during the flow through the pipe.

Mr. C. B. Albree, M. Eng. So. W. Pa.—I arrived at the conclusion that Mr. Diescher has in this way. Supposing that we had a body with a given constant velocity, and afterwards we pushed on this body with a given force. Then the velocity would continue to increase as long as that force continues. We would have our original velocity plus the new velocity due to the new force. It seems to me that is exactly what we would have here, the original velocity due to the height of the water at the entrance of the pipe, and then in addition whatever velocity came from the fall of the pipe down to the top of the barometric column. That force is nothing at the top of the pipe and the maximum at the bottom, therefore he takes the mean and adds that to the original velocity, which we can translate into terms of pressure.

Mr. W. C. Hawley, M. Eng. So. W. Pa.—I learned a long while ago that if we balance equal weights at equal distances from the center, we have a condition of equilibrium. That is the exact

condition in the matter of the atmospheric pressure on the reservoir and the atmospheric pressure at the end of the pipe. If an experiment of that kind could be conducted in vacuum I think it would settle the question very quickly as to whether or not the atmospheric pressure enters into this question at all.

It is not a question of the weight of the water in the pipe, it is a question of head. If this formula which has been derived is applied to such conditions as exist about Pittsburg, with 500 and 600 feet head, you will not find such close agreement with the results obtained by these other formulae, as has been obtained in the case which has been computed.

When we come to consider hydraulic formulae we must remember first, that many of these formulae were derived by experiments in pipes with very small diameters, copper pipes, glass pipes, and pipes of different kinds, and of course they got different results. We must remember also that the degree of roughness of the inside surface of the pipe affects the flow of the water; the diameter of the pipe affects the flow of the water, although this fact is not considered in the formula proposed. We are unable to give these things an exact mathematical value. As the velocity changes, the effect of the degree of roughness changes, then too we are often unable to measure the diameter exactly, or it may vary in different parts of the same pipe line.

We may figure that we have a 12″ or 24″ pipe, but when we come to measure it we find quite a little variation, and if these pipes are of still larger diameter, say over 36″, there is quite likely to be variation due to their being out of circular section. With all these variations coming into the problem we have an equation to solve in which we have three or four unknown quantities, and we cannot expect to get a formula that will give exact results. The only thing to do is to approximate to that result, and that is what we ordinarily do in practice.

I think it would tend very much to simplify this problem if Mr. Diescher would sketch the hydraulic grade line which he would get according to his idea of this problem, and show just what pressure would exist at different points.

Mr. Samuel Diescher—The atmospheric pressure at the foot of the pipe is precisely the same as that upon the water in

the reservoir. Therefore, as far as that is concerned, there would be equilibrium. If we fill an upright pipe with water to the height of 34 ft., cap the upper end, and maintain therein a vacuum, that column of water will stay there. But if even the smallest quantity of water is injected into that pipe, the whole column moves downward by reason of its overweight over that of the atmosphere. Is there the slightest reason to assume that this phenomenon occurs only in the physical laboratory? The pressure that sustains that 34 ft. column is always on hand and active.

What is it that makes a syphon work continuously when once started? Is there any particular agency engaged, or what happens there?

If we set two tanks close together and fill them with water to the same level, take a U shaped pipe and fill it also, close both ends while under water, with corks, then place it across the walls of the tanks so that each branch is submerged, pull the corks, and nothing will happen. But if we lower the water in either one of the tanks, immediately a flow is induced through that pipe, from the higher to the lower water level in those tanks. Why? Because there is now in the branch at the lower level an additional body of water that acts against the atmospheric pressure at the lower side, and, therefore, the atmospheric pressure on the higher water level does not meet the full atmospheric pressure at the other side, because the pressure bearing on the lower level is reduced in its effect by the weight of that additional column on that side of the tube. In consequence of this, the atmosphere's pressure on the higher level, being underbalanced, forces water up the tube whence gravity draws it down on the other side. This performance continues as long as the water levels in the tanks are uneven.

An experiment in a vacuum would not establish any facts in this problem, because the whole question revolves around the effect of the atmosphere's pressure. But it could be solved if the experiments were being made in the atmosphere and with quicksilver instead of water. By reason of the high specific gravity of that substance, apparatus of so moderate dimensions can be employed as to permit their use in rooms. The results thus attained would be just as useful and reliable as those gained by Gallileo and Atwood in ascertaining the laws of gravity.

As to the "head being the essential element" it may be said, that if water were of the same specific gravity as air, no amount of head would induce motion. Head is merely a dimension and is of significance only in connection with pressure.

The pressure that a given quantity of a substance exerts depends upon its specific gravity. If we have two columns of liquid matter of equal heads and sectional areas, the one being water and the other quicksilver, the difference in mechanical effects would not arise from the heads, but from the pressures.

It is remarked that the formula presented "takes no cognizance of the diameter of the pipe."

The co-efficient F is the friction head of a pipe of given diameter and length, at a given velocity, and is derived from actual tests. The co-efficient 0.33 used in calculating the example quoted from Fanning, is taken from "Weston's Friction of Water in Pipes," and is for a 12-inch cast iron pipe of 1,000 ft. length at a velocity of one foot per second. It is evident that having the co-efficient of friction head of a pipe of given diameter, there is no further cause for the introduction of the diameter, for it is actually embodied in the co-efficient F.

As it is the purpose of this paper to establish the theory of the flow of water in pipes fed from reservoirs, it must be limited to this one task. The resistance arising from friction, variations in diameters, bends, joints, etc., is not capable of theoretical investigation, but can be ascertained only by experiment on a very large scale. The co-efficients so found must be entered into this formula in order to gain practical results. If in applying the formula herein presented, to a case with a head of say, 500 or 600 ft., the results do not agree with those obtained by other formulas, it does not signify that this formula is necessarily wrong, for it stands to reason that if this theory is right, then the others may be wrong, and vice versa.

Concerning the fact that it is impossible to get exact results by any formula, or theory, for that matter, and that we must be content with approximations, does not prove that there can possibly be a mechanical action that has no theory. Such a thing does not occur in nature. The difficulty is in finding that theory; there can be no doubt that it exists. If after the establishment

of the true theory we can still only approximate actual conditions, it must be ascribed to the presence of those incidental agencies that cannot be brought within a theory, such as impediments of all kinds. But this much is certain that if the true theory is once found, the approximations will come nearer the facts than now.

Mr. W. C. Hawley—The Chezy formula with the co-efficients generally used agrees very closely with the experiments that have been made. I would refer you to Herschel's "115 Experiments."

Our test of a theory must be a practical one and it must take into consideration all the practical matters such as the roughness of the pipe, friction and all that sort of thing.

The reason why I spoke of a hydraulic grade line is this: In accordance with this formula with 500 ft. head we simply throw away 218 ft. Now any one who has had to do with the maintenance of pipe lines knows very well that there is no such amount of head thrown away. We have a pressure gauge in our office and we watch it every day and we have cases where pipes break and large quantities of water go to waste, but we never get down to anything like that. At the same time we have consumers on our pipe lines at a point right at the reservoir and these consumers are all supplied. The question of a vacuum in the pipe entering into this has caused, I think, some confusion. We don't find in practice that a vacuum will exist after the valve has been opened and water allowed to enter the pipe.

Mr. Samuel Diescher—The loss of head is not real but only apparent.

Supposing we have a reservoir filled with water, the surface of which is 100 ft. above a certain point, at which we erect a pipe 100 ft. high, and connect its foot with the reservoir, so that the pipe may be filled even with the water level in the reservoir. At the point of connection with the supply pipe let there be a valve, by which the water may be turned on or off, according to requirement. Let us drop a piston into that pipe, that shall go to the bottom of the pipe. Now, if we turn on the water, that piston will rise, because it is subjected to a lifting force of 43.4 pounds on every square inch of its area. But that pressure decreases right from the beginning at the rate at which the piston approaches the top of the pipe, that is, inversely as the column

of water in that pipe grows, so that when the piston reaches the height of 50 ft., the pressure against its lower surface is only half what it was at the beginning, and when the piston has risen to the top of the pipe, there will be no pressure at all. If we choose to call that height the "head" and wish to ascertain what work was performed during the ascent of the piston, we find that work will equal half the head times the initial pressure at the foot of the pipe, or half the initial pressure times the whole head. Is there really anything lost if we say: The effect of that column of water is equal half the head times the maximum pressure? If water flows through a long pipe in which the continuous resistance from various causes is such as to very materially reduce the velocity at which the flow would occur if there were no resistance, then work is performed in overcoming that resistance. And if the force that produces the impulse, is variable, then we must take the mean effective force and multiply this by the head, or if that force is uniformly growing from zero to maximum, we get the same result by multiplying the maximum force with half that head. But whichever way we may select to follow, the result will be the same and we get what there is; neither more nor less.

On the other hand, let us suppose that said pipe be also connected with a boiler and that we can employ steam of 43.4 pounds pressure. In this instance the piston performs its whole stroke at a pressure of 43.4 pounds; and now the work performed is just twice as much as when using water of equal initial pressure, yet the head is the same as before; and why this result? Because in the first case the pressure varied, and in the latter it is constant, and therein lies the difference in the results.

If we draw a vertical line to a scale, representing the head in the pipe less the barometric column, and draw from the foot of that line a horizontal line according to any scale, representing the intensity of the pressure at the foot of that head, accruing from the column of water within that reduced pipe head; and if then we connect the ends of those two lines by a third line, we have a triangle whose area represents the work in foot pounds contained in that column. This area is found by multiplying the base of that triangle by half the height.

Mr. C. B. Albree—Mr. Diescher, your formula is based

on a full pipe. Have you considered what would be the effect if the inlet were only partially open so that it would not allow the pipe to be filled?

MR. SAMUEL DIESCHER—This could occur only in a horizontal pipe, and not in one that has a fall. But I do not think that need be entered into at all because the question is as to the capacity of the pipe when full.

MR. F. G. ROSS, M. Eng. So. W. Pa.—Mr. Diescher has carried his demonstration from point to point and brought very good evidence to prove all the assertions made and his results are certainly startling. He, however this evening, has made a statement which does not appear in the text of his paper, but which is necessary to explain the great difference of effective head secured by the use of his formula. This statement is: "That the energy required to put a certain volume of water into a reservoir by means of a pumping plant is not the same as that used to produce velocity when this head of water is released and flows downward through the pipe." It seems to me that none of his demonstrations have thrown any light on this statement, and it is at variance with the fundamental teachings of physics. Taking his own example of 500 ft. head producing an effective head of only 282 ft. What becomes of the 218 ft. head that he considers non-effective? It is not consumed in friction for his formula for velocity has a friction factor, and as head can only produce velocity and friction it must produce velocity.

MR. SAMUEL DIESCHER—There is no actual loss of head; this misunderstanding arose from the fact that considering both head and pressure in the calculation, to ascertain the amount of work performed or the energy contained in the column whose height is the head, we must consider the energy on which we may count in performing the work of overcoming the friction, etc. If we select the maximum pressure as one of the factors, we must take for the other, half of the head, and the product of this is the work, and this can be graphically represented by a rectangle of which one side is the mean effective pressure and the other the head.

To pump water to an elevation takes theoretically just as much energy as that same water develops in its descent from that

elevation. In practice there is a difference due to the resistance that the flow meets in both directions.

MR. W. C. HAWLEY—It is not a question of the whole pressure being effective at any one point but it is a question of the distribution of that pressure throughout the length of the pipe so that at no point is there a pressure less than will overcome the friction. If we reduce it to the condition that exists in a sewer, where there is a uniform fall simply sufficient to overcome the friction and maintain a uniform velocity through the sewer, then this method of figuring, I think, could not be used. Mr. Ross's point is well taken. The energy stored in putting that water up into the reservoir certainly must come out when that water comes down the hill; and we must consider the whole head. We cannot throw away any part of it.

MR. SAMUEL DIESCHER—What I want to say is, that head and energy are not one and the same thing, and that the head enters the calculation only because the energy in the column of water grows in a straight ratio with the head.

MR. A. STUCKI—What these gentlemen say would be perfectly right provided we had no friction at all, then the energy necessary to raise or pump the water into the reservoir would be the same as what we get out of it if it falls, no matter at what velocity this takes place.

MR. W. C. HAWLEY—There is the same amount of friction in putting it up the hill that it looses in coming down.

MR. SAMUEL DIESCHER—That is not energy, that is waste.

MR. F. G. ROSS—We assume that this comes down with the same velocity that it goes up. You lose just the same one way as the other. I had not previously taken into consideration the atmospheric head for it seems to me that the whole demonstration as carried out by Figs. 1, 2, 3, 4 and 5 has proven nothing but the conceded fact, that the pressures of the atmosphere at the inlet and at the outlet are balanced forces. That the atmospheric pressure assists and is necessary to the entrance of water to a syphon is proven by the fact that a syphon will not work in a vacuum but water will flow from a reservoir to a pipe in a vacuum. Hence the demonstration of a syphon cannot enter. But, since Mr. Diescher takes this atmospheric head into

consideration and takes 34 ft. from the head in the pipe when this head is more than 34 ft., I do not understand why this same 34 ft. should not be taken from the head when the head in the pipe is less than 34 ft. It seems to me that the resistance to outflow at the end of the two pipes is identical.

Mr. Samuel Diescher—What I demonstrated in figures 1 to 5 are conceded facts in a general way, but not as to their present application, namely the maintenance of an inert column of water at the efflux that is set in motion not by its own weight which is neutralized by the atmosphere's opposition to the efflux, but is moved by the head in the upper portion of the pipe, the head in the reservoir, and the atmosphere's pressure upon the water in the reservoir. In short, the impelling effect that the 34 ft. column of water at the efflux would exercise if it were not for the opposition of the atmosphere, is transferred to the reservoir. Why 34 ft. of a column is not rendered ineffective if the entire pipe head does not amount to that much, is demonstrated by Figures 8 to 11. The statement that the "demonstration of a syphon cannot enter" is entirely wrong. The action of a syphon is based upon the phenomenon understood by the term suction. But what is suction; is it something like magnetism, or what? Well, it is the tendency of the atmosphere to fill out a vacuum. Does suction occur where there is not at least a tendency to produce a vacuum? No. Consequently there must be in the descending branch of a syphon some action that tends to produce a vacuum. The cause of this is the unbalanced excess of column on the descending side over that in the rising branch. However little or much that excess may be, it has its effect upon the atmosphere's pressure against the efflux. If the water in two adjacent tanks connected by a syphon, is on the same level, then there is equilibrium and rest, because as the gentlemen have repeatedly stated, the atmospheric pressure at both ends of a pipe is the same, the condition is the same as if on a balanced lever equal loads rest at equal distances from the fulcrum. Nobody will dispute this, but this state exists in connection with a syphon only when the surface of both bodies of water are on the same level. The moment that one of them sinks, there is a longer

column of water on the sinking side than on the other; still the two atmospheric pressures are precisely the same, but on the one side there is some water thrown on the scale, that disturbs the equilibrium and thus induces motion because it is in excess of the atmospheric pressure.

That small or large excess of water in the syphon caused motion, it produced work in as much as it gave cause to water rising in the other branch; is this not proof that the excess of water on the descending side had to overcome the resistance of the air opposing the efflux, for how else could it have created a void into which the atmosphere at the other end forced water? But if a descending column of water in a syphon caused motion in its wake, why should the same not take place in a perpendicular pipe from a reservoir, without a gooseneck? There is no fundamental difference between the two cases.

Mr. F. W. Winter, M. Eng. So. W. Pa.—I cannot express any positive opinion upon the correctness of Mr. Diescher's theory, except to say that it appeals to my reason. There are some factors in it, however, which I know to be fundamentally correct, and as it seems to me that the reasoning is based upon sound premises, I am inclined to believe that the conclusions are correct.

One of the premises that I have recognized to be sound is that which is illustrated in Figure 5 of the diagram. There is shown an application of a principle found in some filter systems, which I think are in quite extensive use and with which most of you are familiar. Take an ordinary granular bed or sand filter. It is well known that water can be forced through the bed at different velocities depending, not only on the head of the water, which is above the sand, but also upon the drop or downward fall of the outlet pipe. If the outlet pipe extends downward for a considerable distance, it draws the water through the filter bed with greater velocity than is given by the head of the water on top of the bed. Figure 5 of the diagram illustrates the principles of the negative head of the filters. And it also illustrates that if the negative head is continued downward more than 34 ft., there will be a vacuum in between the point of resistance, that is; the filter bed, which corresponds to the disc in the dia-

gram, and the top of the column of water in the pipe below. All filter experts concede that the suction, as they term this negative head, increases in proportion to the drop of the outflow pipe, up to 34 ft., and then it no longer increases.

This is in exact agreement with what Mr. Diescher has stated, and shows quite conclusively that there is the factor of the barometric column which must be taken into consideration in all of these calculations.

This may be another explanation of the question which Mr. Stucki first put to Mr. Diescher, viz., why he should take the mean of the drop of the outflow pipe in excess of 34 ft. and not take the mean of the head of the water in the reservoir. Look at Figure 5 for a moment. If we suppose that the reservoir is sealed on top, so that it is air tight, we would have at the lower part of the outflow pipe a column of water 34 ft. high due to the barometric column; we would also have a reservoir depth of water marked 15 ft. in that figure; then we would have a vacuum in the space between the two, which is the portion of the outflow pipe in excess of 34 ft. Now if we could imagine that vacuum to be filled with water we would have it practically suspended. It seems to me to be reasonable, with a column of water held in suspension so that there is no pressure on top of it, to take the mean of that column of water, instead of the entire weight thereof.

THE ASSAYING OF TIN AND TERNE DROSSES.*

BY GEORGE P. MAURY,

Member Engineers' Society of Western Pennsylvania.

These drosses are a heterogeneous mixture of the metal buttons from about 5 grams in weight down to a size that will pass through about a forty mesh sieve, with oxides of tin, lead, iron, and zinc, zinc chloride, silica, alumina, partly burned carbonaceous matter, etc. It can readily be seen that a very large variation in results may occur unless special precautions are taken to put the sample in such shape that a correct average may be obtained in the portion taken for the assay.

The dross is received in two portions, together with the percentage of each in the car sample; the coarse, that did not pass through a twenty mesh sieve, and the fine, that did pass through a twenty mesh sieve in sampling.

The relative amounts of fine and coarse vary widely, running from .25% coarse to .20% coarse, depending upon the richness and physical condition of the dross.

The conditions naturally divide the method of analysis into, and we shall consider it under three heads: The Preparation of the Sample, The Assay and the Analysis ofthe Button from the Assay.

PREPARATION OF THE SAMPLE.

Under this head I will describe two methods, either of which gives good results:

Method by oxidation.

Method of separating the coarse from the fine, and weighing each portion.

Method of separating the coarse from the fine.

For convenience we will call the original coarse sample A and the original fine sample B; for example, we take a dross con-

*Read at meeting of the Chemical Section, Dec. 22, 1904.

taining 10% coarse, which we call A, and 90% fine, which we call B.

All of A is taken, in this case two hundred grams, ground until everything will go through a one hundred mesh sieve, except the metal beads or buttons, these are flattened out, the object in so doing is to be sure that all the small pieces of brick, gravel, etc., are broken up, and to know that nothing of the kind is left with the buttons of metal; after this operation there are (see calculation) fifty grams of fine, equal to 25%, and one hundred grams of coarse, equal to 75%.

For a three hundred gram sample there would be 10% of three hundred grams, or thirty grams of A, and 90% of B, which is equal to two hundred and seventy grams.

The two hundred and seventy grams are ground until everything except the metallic buttons will pass a one hundred mesh sieve, the buttons are flattened as described above under the coarse. Upon weighing the coarse and the fine the coarse from B equals 30 grams, which is 11.11%, and the fine equals 240 grams or 88.89%. The coarse from A was 75%, and there would be required for a 300 gram sample 30 grams of A, then 75% of 30 grams equals 22:50 grams from A, and 11.11% of B equals 30 grams of coarse, or a total of 52.50 grams, equaling 17.50% of coarse.

These amounts are weighed out and mixed.

For the fine we had 25% of B or 25% of 30 grams, equal to 7.50 grams. Of the fine in B there was 88.89% of 270 grams, equal to 240 grams; a total of 247.50 grams, equal to 82.50% of 300 grams, the amount of the sample taken. These are thoroughly mixed.

Then the assay sample will consist of 17.50% coarse and 82.50% fine. On a 20 gram assay this would be 3.50 grams of coarse and 16.50 grams of fine.

CALCULATION.

10% course A 90% fine B	300 gram sample equals	30 grams of A 270 " " B
A yields	Fine 50 grams equals Coarse 150 " "	25% 75%
B yields	Fine 240 grams equals Coarse 30 " "	88.89% 11.11%

New sample :—

Coarse	10% of A equals 30 grams 75% of which is coarse equal to - - - -	22.50 grams
	90% of B equals 270 grams 11.11% of which is coarse equal to - - -	30.00 "
	Total coarse equals 17.50% -	52.50 "
Fine	A 10% of 300 equals 30 grams 25% of which is fine equal to - - - -	7.50 grams
	B 90% of 300 equals 270 grams 88 89% of which is fine equal to - - - -	240.00 "
	Total fine equals 82.50% - -	247.50 "
Assay sample	Coarse equals 17.50% } for 20 gram sample	3.50 grams coarse
	Fine. " 82.50% } for 20 gram sample	16.50 " fine

Oxidation method. About 400 grams of the sample accurately weighed are taken, placed in a large evaporating dish (12 in. in diameter) moistened with water and nitric acid added very cautiously at first, then heat gently until solution is complete. It usually takes about as many cubic centimeters of nitric acid to oxidize sample as grams of sample taken (this may vary, of coarse, as the dross is rich or lean in metallic particles). Add cautiously enough sulphuric acid to replace nitric acid left, (usually about 1/3 to 1/4 of amount of nitric used), evaporate to dryness and heat to drive out nitrates and as much sulphuric acid as possible, break up mass and grind to pass a 100 mesh sieve, then heat to a red heat for at least one hour to decompose all sulphates (to prevent trouble from boiling over the top of the crucible, also to reduce amount of potassium cyanide required in assay) allow sample to cool and weigh accurately; sample will weigh more on account of oxygen taken up.

We find it weighs 504 grams, which divided by 400 (amount of the sample taken) equals 1.26, which is the factor by which to multiply the result obtained in assaying, that is, if the sample shows 30% of the metal by assay, this multiplied by 1.26 equals 37.80%, the amount in the original dross.

The Assay. Take 20 grams of the sample and 100 grams of potassium cyanide in a "G" or "J" crucible, mix the sample with about 50 grams of the ground cyanide, and place about 40 grams of the balance in the bottom of the crucible, then add the sample mixed with the cyanide, settle well by tapping, and add the balance of the cyanide, spreading it in a thin layer over the top of the sample.

A blacksmiths forge is used to reduce the assay and it is very satisfactory. While authorities on assaying tell you to use a bright red or white heat, our best results have been obtained above a white heat, in fact as high as an air blast and a coke fire will give in a forge just short of melting a Denver crucible.

High temperatures has given the highest results and low temperatures invariably gives low results. The crucible is allowed to stay in the furnace from five to ten minutes after fusion begins. The high iron content in the dross and the button, raises the fusion point of the button and makes the high temperature necessary for a correct assay. The crucible is allowed to cool and is broken, the button is thoroughly cleaned, boiled in water, dried and broken up by hammering and is washed again in boiling water, dried and weighed as a check on the direct determinations of the contents of the button.

Analysis of the button. After weighing the button it is dissolved in hydrochloric acid with a small amount of nitric acid, diluted to one litre and fifty cc. or one twentieth of the solution taken for the determination of iron by titration with potassium bichromate.

Fifty cc. is taken for the determination of tin, copper, zinc and lead, this is made nearly neutral, thirty cc. of ammonium sulphide solution added and digested for about thirty minutes. Hydrogen sulphide is passed through the solution and the solution filtered. The iron, lead, copper and zinc are dissolved off the paper with strong hydrochloric acid and a few drops of nitric acid, boiled and brought nearly to neutral point with ammonia; thirty cc. more ammonium sulphide added and digested as before. Usually three ammonium sulphide separations are necessary to separate the tin from the other metals.

The iron, lead, etc., are then dissolved as before, sulphuric acid added, and evaporated until fumes of sulphuric anhydride are given off, for lead by the sulphate method. Make double hydrate of filtrate for zinc and determine by hydrogen sulphide and sodium carbonate.

The precipitate of iron is next dissolved and tested with hydrogen sulphide to see if any tin has gone through with the iron.

The filtrates from the ammonium sulphide digestions are combined and made slightly acid with sulphuric acid to precipitate the tin as a sulphide, it is filtered, thoroughly washed with hot water, burned and weighed.

Extreme care is exercised to prevent volatilization of tin as proto-sulphide. Ammonium carbonate is added to remove the last of the sulphuric anhydride.

When percentage of iron is high in an alloy of tin and iron, the separation of tin by oxidation with nitric acid is unsatisfactory as part of the iron will be carried down with the oxide of tin and some of the tin will go in solution with the nitrate of iron.

Separation of tin and iron by hydrogen sulphide in acid solution gave very unsatisfactory results; if the solution is acid enough to hold up the iron, some of the tin will be held in solution, and if all the tin precipitates some iron will be carried down with it.

The separation with sodium sulphide proved unsatisfactory on account of trouble in washing out sodium salts.

OPEN-HEARTH FURNACES.*

BY G. L. LUETSCHER.
(Non-member.)

It is a difficult matter to read a paper on open-hearth furnaces in which that subject should be more exhaustively or ably treated than in H. H. Campbell's "Manufacture and Properties of Iron and Steel," and F. W. Harbord's "Metallurgy of Steel." It was the request of your Program Committee that I give a description of the open-hearth furnace in popular form and if critical minds cannot discover in my paper any information particularly new to the open-hearth furnace specialist they will kindly consider that it is prepared for "lay-men in the open-hearth line." The illustrations are taken partly from above mentioned publications, partly from European sources to avoid publishing drawings which by right of purchase or as original designs are not public property nor drawings whose publication might serve for advertising purposes.

The open-hearth furnace is a furnace in which by combustion of gaseous fuel according to the regenerative system invented by Sir William and Fred. Siemens such high temperatures are obtained that on its hearth metals like iron and steel can be melted and treated while openly exposed to the physical and chemical action of the flame. Hence its name, "open-hearth," in contra-distinction to other furnaces (formerly the only ones in use) in which the less fusible metals are melted inside of a closed receptacle, the crucible.

The furnace consists of a melting chamber, "the hearth," the walls and roof of which are built of the most refractory bricks obtainable, while the bottom on which the metal is melted and treated, is made of a material which is not only very refractory, but also resists the chemical action of the slag which may be either acid, basic or neutral.

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*Read before Mechanical Section, February 7, 1905.

On both ends of the hearth are openings, "the ports" for the gas and air, which enter separately through ducts in this end-brick work, called "the block." Before reaching these ducts, the air and, if producer gas is used, also the gas, are preheated by passing over hot firebricks piled in large chambers, "the regenerators." There are two sets of regenerators, one arranged to connect with one end, the other with the opposite end of the furnace hearth. The air and gas enter through the bottom of these regenerators at one end, ascend to the top passing over the "checker" bricks which are carefully piled so as to give the greatest possible surface for absorption and regeneration of heat, and enter, still kept separate from each other, through up-takes and the ports into the hearth and combine here, forming a flame of great intensity. The products of combustion, the waste gases, go out through the ports on the other end of the hearth, descend through the regenerators at that end and give up their heat to the checker-bricks and finally pass to the stack. The course of gas and air, and the waste gases respectively is reversed at certain intervals, generally every 15 to 20 minutes, and thus, by accumulation, very high temperatures are gradually obtained and maintained in the melting chamber which are necessary to keep soft steel ("Flusseisen") in fluid condition with a surplus of heat necessary to permit its removal into a ladle for the pouring into moulds for ingots or castings. By a system of valves the quantities of gas and air admitted to the furnace are regulated and the alternating connections by means of flues are established respectively between one set of regenerators with the gas main, and the outside air on one side, and the other set of regenerators with the stack on the other side. The same principles of heat regeneration are used in furnaces for heating purposes only and a steel-melting furnace only differs from a regenerative heating furnace in the quality and intensity of the flame. Heating furnaces are generally operated with a reducing mild flame and much of the heat is acquired by the material to be heated, by radiation from the roof. The temperatures maintained are regulated according to the material to be heated, the regenerators are therefore smaller or are omitted for the gas.

The construction of the open-hearth furnace presents a large amount of variations according to size, local conditions, theoretical notions and practical reasons of the furnace man and builder and has been brought to some fine points of detail.

The hearth of the furnace is mostly rectangular in shape, seldom oval. Some attempts have been made with round hearths. They are, however, of use only for the melting of large chunks of scrap, sinkheads of large castings, etc., into more easily handled shape for another remelting, as they permit the use of a removable roof. The hearth should be as long as possible to allow a full development of the flame. It has been found by practice that the length from port to port should be at least 20 feet for furnaces of moderate size (say 15 to 25 tons), for larger furnaces not less than 24 feet, 27 and more feet being preferable. The width varies from 10 to 15 feet. The roof is generally built of 9-inch silica bricks. Thirteen-inch roofs have given good satisfaction and shown a correspondingly longer life than 9-inch roofs, the only difficulty resulting from the warped surface of the 13-inch bricks. The roof should not be much higher than to permit the use of doors of proper size and the use of a charging machine. It forms a fairly flat arch. Too flat a roof is liable to sag and cave in. On the contrary, if the radius of the arch is too small, the roof has a tendency to open on the crest when heated and afterwards to sag in front over a door, or in the back over the tap hole, or on a place where the roof has become thinner by being burned and partially melted off. The skew back is generally held by channels and should preferably be suspended independently of front and back walls to permit repairs of the latter without interference with the roof. The skew back channels are held together by buckstays and tie rods forming the binding of the furnace. Sometimes there are springs put between the nuts of the tie rods and the buckstays to permit the expansion of the roof. This is a good construction but has the disadvantage that the furnace tenders who are to watch and let out or tighten the rods when a furnace is heated up or cooled down, rely too much on the springs and neglect their own attendance. The roof may be high above the bath and straight from end to end to permit

the use of heat by radiation. But this advantage is rather a problematic one as it has been demonstrated that furnaces with such roofs do not work fast nor with a low fuel consumption. It is after all the impinging flame of considerable luminosity, caused by the incandescence and combustion of carbon particles of hydro carbons and gas rich in carbonic oxide, which does the best work for melting and therefore the practice has developed to draw both ends of the roof down as much as possible in order to hold the flame down on the bath. I prefer a roof construction as shown in Fig. 1. Some furnace men consider it better practice to build the roof higher in the middle as shown in Figs. 3 and 5. This construction though offers more practical difficulties to the bricklayer, but is less liable to allow the roof to fall in, on account of the double arching. The front and back walls are built up straight, not less than 13 inches thick, as shown in Fig. 8, or, to prevent tumbling in, slanting as shown in Fig. 2. In acid furnaces they are built of silica bricks entirely, in basic furnaces of silica bricks in the upper part and of magnesia bricks in the lower part to some height above the slag line. There are usually three charging doors in the front wall, sometimes in larger furnaces with long hearths there are also two smaller doors for repairing the ends. The door frames are held fast to the brick work by the buck-stays or are fastened to the same by bolts, often constructed so that the cheek-pieces can be easily replaced when burnt off. The door frames as well as the doors are frequently cooled by water running through cast-iron pipes in the frames and in open pockets in the doors. This makes the work of the furnace men easier in the summer and saves repairs. It is however, rather expensive unless water is quite cheap, and dangerous in case of water stoppages. The doors are either lifted by hand by means of levers, as in Figs. 1 and 3, or by pneumatic or hydraulic cylinders directly above the doors, as shown in Fig. 5, or on one end of the furnace, fastened to the binding. The hearth itself is first built of the best clay bricks in acid furnaces or of magnesite bricks in basic furnaces (Fig. 1, 2, 5, 7 and 8) or of chrome-ore lumps (Fig. 4). In an acid furnace the bottom is then burned in with not too pure a quality of silica sand, in a basic furnace

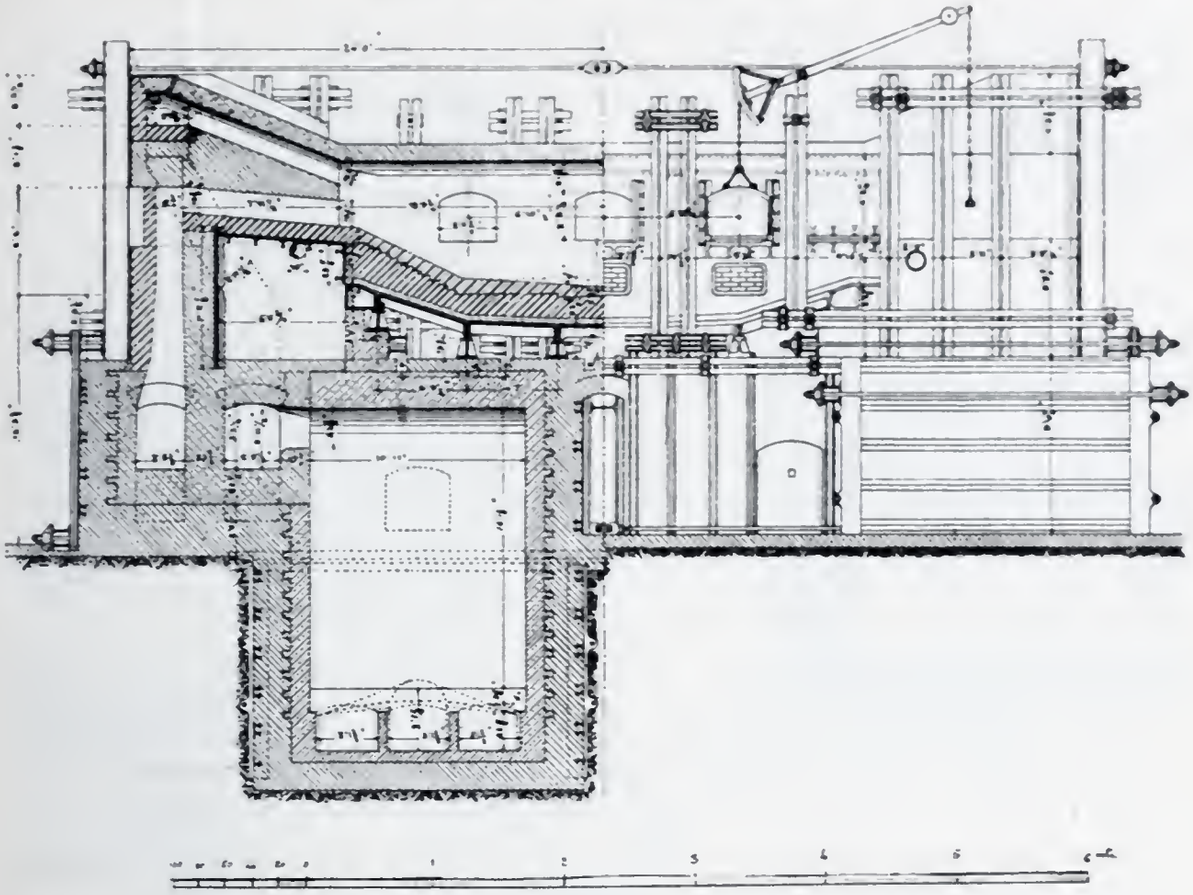


Fig. 1. Thirty-ton Basic Open-hearth Furnace at Donawitz, Austria.

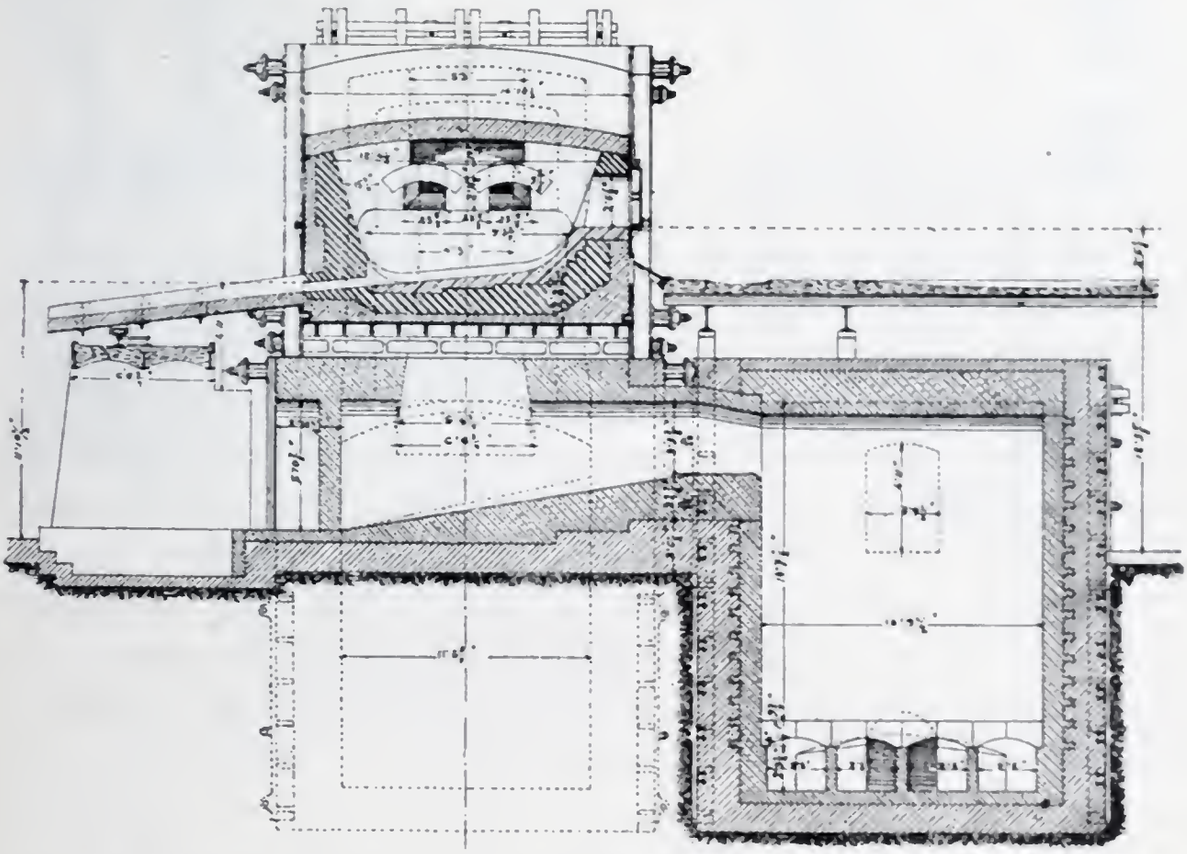


Fig. 2. Thirty-ton Basic Open-hearth Furnace at Donawitz, Austria.

with magnesite or dolomite. The hearth casing is made up of cast iron plates (Figs. 1, 2 and 3), which more or less follow the lines of the upper surface of the bottom, or of steel plate, riveted together and are either straight down or tapered. The hearth casing is generally supported by I beams resting on separate piers (Fig. 3), or on the reinforced front and back-walls of the (air) regenerators, or so-called slag pockets (Figs. 1 and 2), or the hearth rests on a solid mass of brickwork as shown in Fig. 5.

The latter construction will prevent all possibility of heats breaking through, but is very apt to lead to the formation of deep holes in the bottom which can cause considerable annoyance in the melting and finishing of the steel. The hearth should never be supported by the regenerator arches.

The binding of the furnace is chiefly made up of I beams and channels, either used in pairs held together by cast-iron shoe-pieces for the tie rods, or singly with plate-loops riveted to the ends for the same purpose. The use of old rails for the binding of open-hearth furnaces is not common to-day. The spout through which the metal runs from the furnace to the ladle is frequently made removable to facilitate a quick approach to the tap-hole after the heat is tapped to avoid any delay in again charging the furnace.

The hearth generally is designed and constructed to give a depth of about 18 to 24 inches of melted metal.

The ports or entrances for gas and air are of the utmost importance for the proper working of the furnace and their construction and size influences the fuel consumption, rapid and sharp action of the flame and the life of the furnace more than any other part. Usually there are two gas ports and two air ports, the latter above the former, as shown in Figs. 1 and 2. Sometimes the two air ports finally form one wide port, their covering assuming the same shape, actually forming a continuation of the hearth-roof. In smaller furnaces, up to 25-ton capacity, there is sometimes only one gas port and two air ports, in which case the ports are preferably placed side by side, as shown in Figs. 3 and 4. The ports must be constructed so that gas and air mix as thoroughly and as soon as possible after leav-

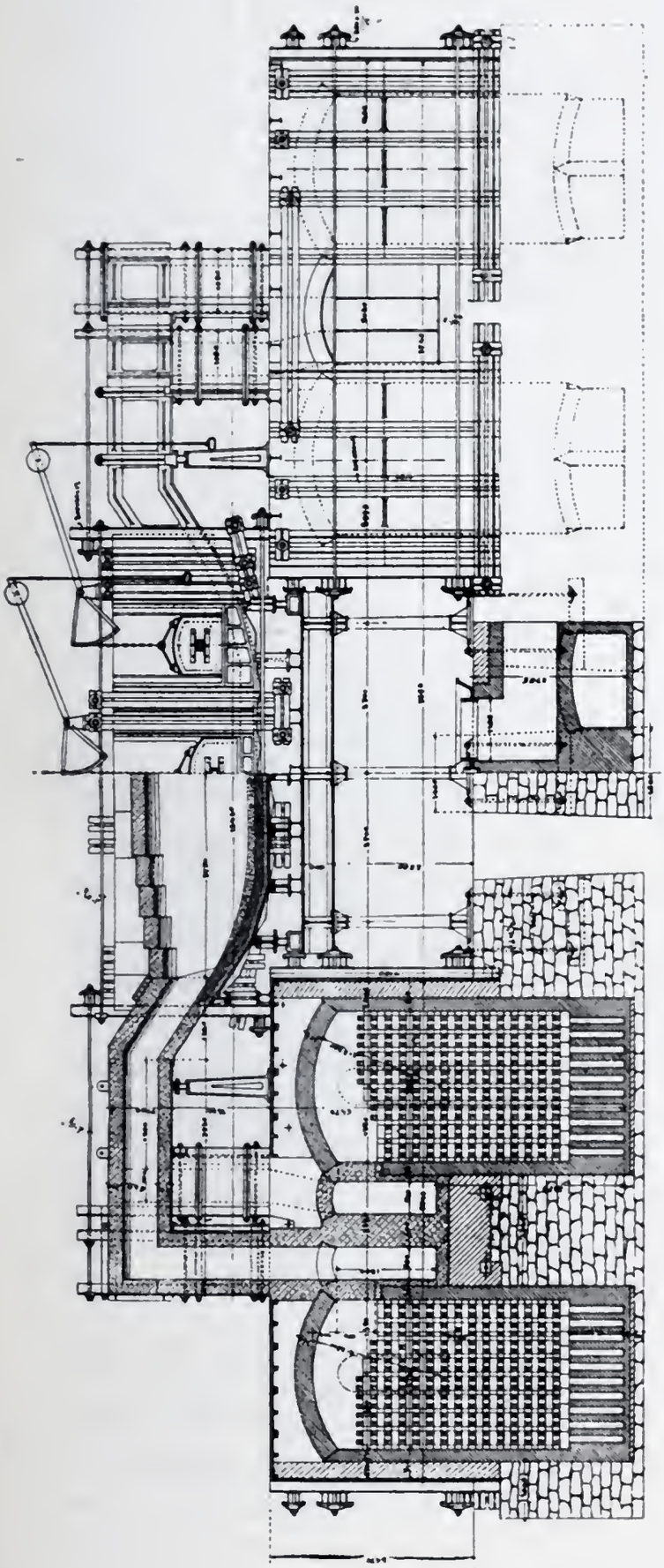


Fig. 3.

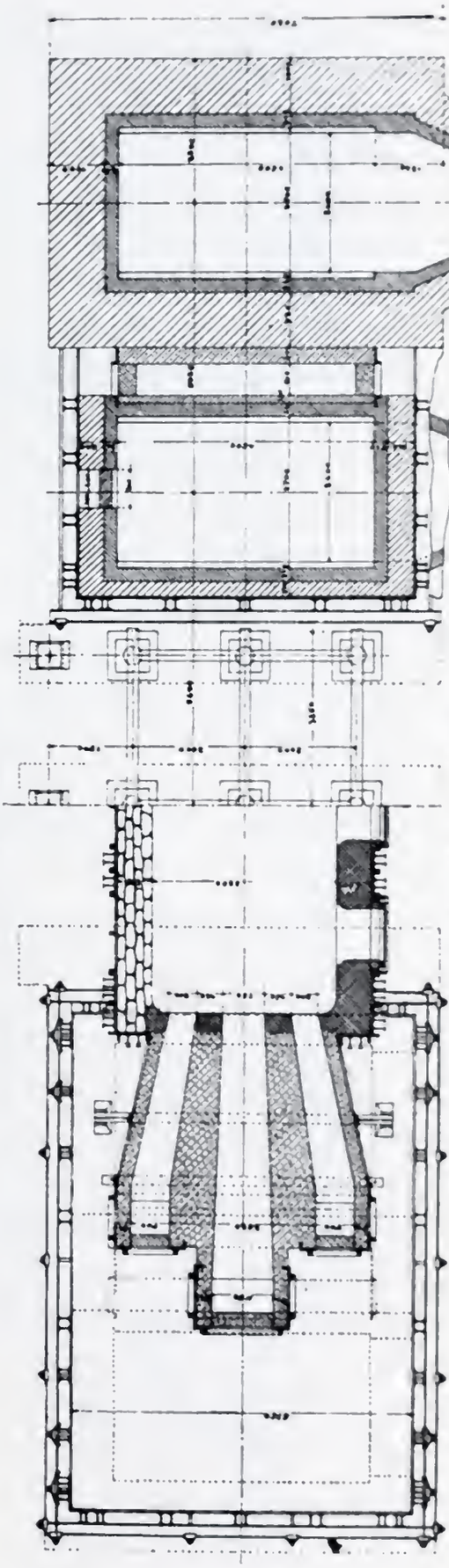


Fig. 4. Twenty-five ton Open-hearth Furnace at Lissva, Russia.

ing the ports and the flame will impinge on the metal bath. The ports generally converge slightly towards the center of the furnace to protect the front and back walls and insure a complete combustion. For natural gas fuel the construction becomes very simple, the gas being admitted only a short distance from the face of the block as shown in Figs. 5 and 7. It is, however, advisable and customary to build such furnaces so that by small changes in the construction of the block, they can be used with producer gas. With tilting furnaces the blocks are made removable.

The uptakes to the ports either form one compact structure or are built and bound separately (Fig. 3). Before entering the uptakes from the regenerators the gas and air usually pass through so-called "slag pockets," whose main object is to collect as much as possible of the materials which are carried along by the outgoing flame and thus partly prevent the clogging of the checker-brickwork (Figs. 1, 2, 3 and 4). The materials collected are fine oxide of iron, sand, dirt, lime and dolomite dust, and form a sticky slag in the pockets which can generally only be removed by sledging when the furnace is cooled down.

The regenerator chambers are built either under the furnace hearth as shown in Figs. 3 and 4, or back of the hearth altogether, under the charging floor. As a rule the outer regenerator is used for the gas, the inner one for the air. Figs. 1 and 2 show a furnace in which the air regenerators are built under the hearth and the gas regenerators back of the hearth structure. The latter construction is the one generally used in the newer plants in the United States. Some furnace men, though, who have had experience in running furnaces of both these constructions, claim that the older construction gives a somewhat sharper and swifter working furnace. It is also cheaper to build and simpler, but takes up more room in the direction of the long axis of the furnace. The space occupied by the checker-bricks should be as large as possible, especially for the air regenerator, its cubic contents for one side of the furnace being about 70 to 100 cubic feet for gas and air jointly per ton of melting capacity. The larger the regenerators the lower the fuel consumption. The proportion of cubic contents of the gas re-

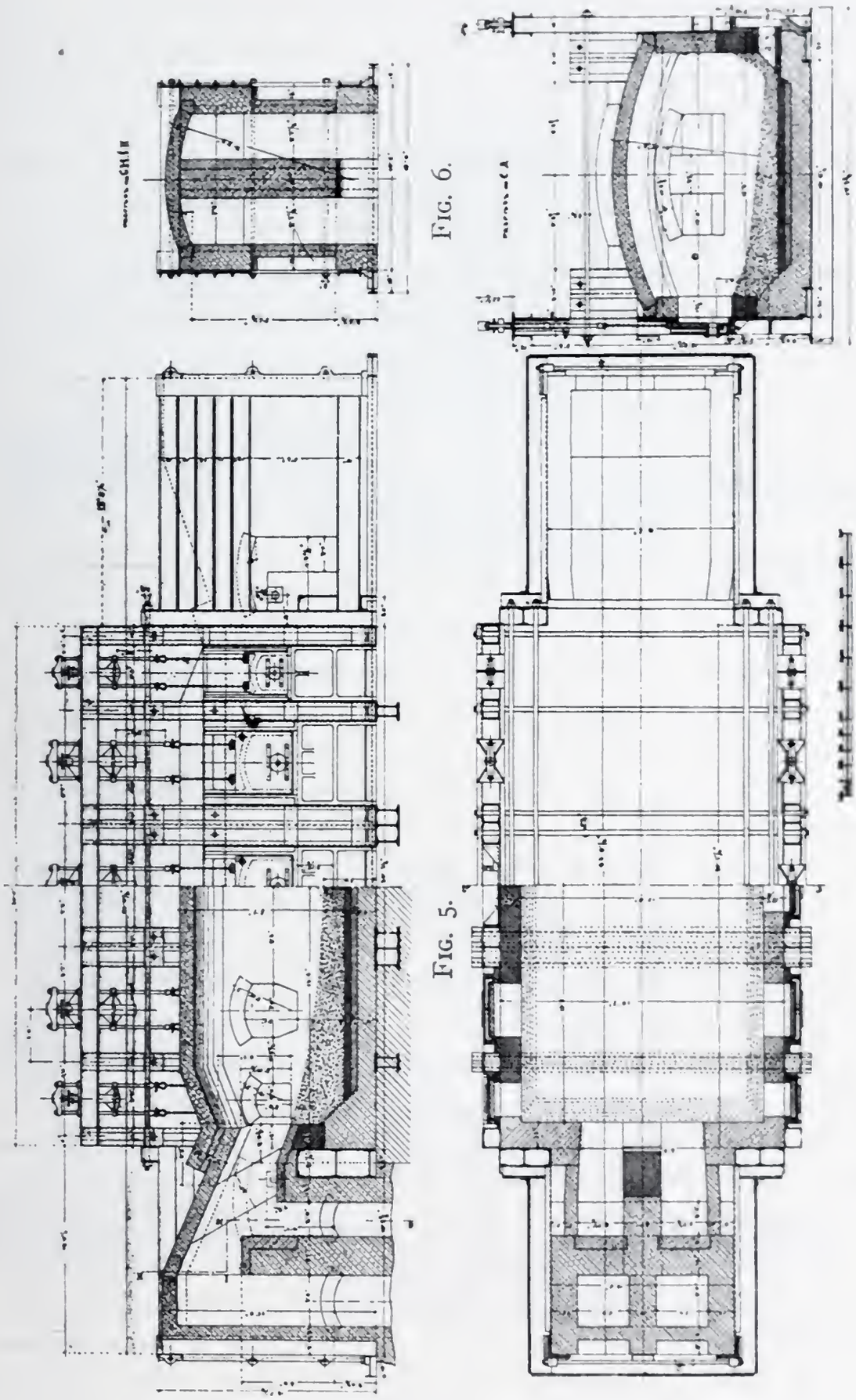


Fig. 5. Fig. 6. Fig. 7. Fig. 8.

Fifty-ton Open-hearth Furnace at Homestead.

generator to the air regenerator is generally made 5 to 8. There is, however, a limit to the size of the gas regenerator which should not preheat the gas to such a degree that dissociation of the gas would take place. The greater the dimension of the regenerators in the vertical direction, the more effective they are, as vertical checker-work takes up the heat of the waste gases and gives it to the ascending gas and air much more readily than those arranged so that the horizontal checker-work predominates. The checker-bricks should be piled well apart from each other so that the oxide of iron dust deposited by the waste gases cannot obstruct the passages. For the same reason the rider-walls on which the rider-tiles supporting the checker-bricks are resting, should be made quite high to allow for some filling up by oxide-dust, especially with furnaces which are intended for melting large quantities of fine loose rusty scrap like sheets and turnings. The flues connecting the regenerators with the reversing valves have to be of ample size to prevent choking; in fact, the whole system of flues, regenerators, uptakes and ports ought to be kept large almost to the end of the port, and with few and easy bends. By this principle it will be found that neither gas nor air have to be forced or sucked into the furnace and that they will by their heat expansion enter the hearth chamber through the port openings with considerable force. The stack flue is supplied with a damper plate. Wherever it is practicable, there should be an arrangement by which the draught through the air regenerators can be regulated separately from that of the gas regenerators. The stack—mostly a brick-lined iron stack—is made large and high, 100 and more feet, for obtaining a good draught. It should, however, seldom have to be used to its full capacity, as it is considered the best melting practice to just barely take away the products of combustion and not to suck the air or gas in by stack draught.

Of reversing valves there are a large number of very varied construction and efficiency. They should be absolutely tight, easily and quickly reversed, simple, compact and easily examined and replaced. The perfect valve does not exist. There are the systems invented by Siemens, the Forter water sealed, the old

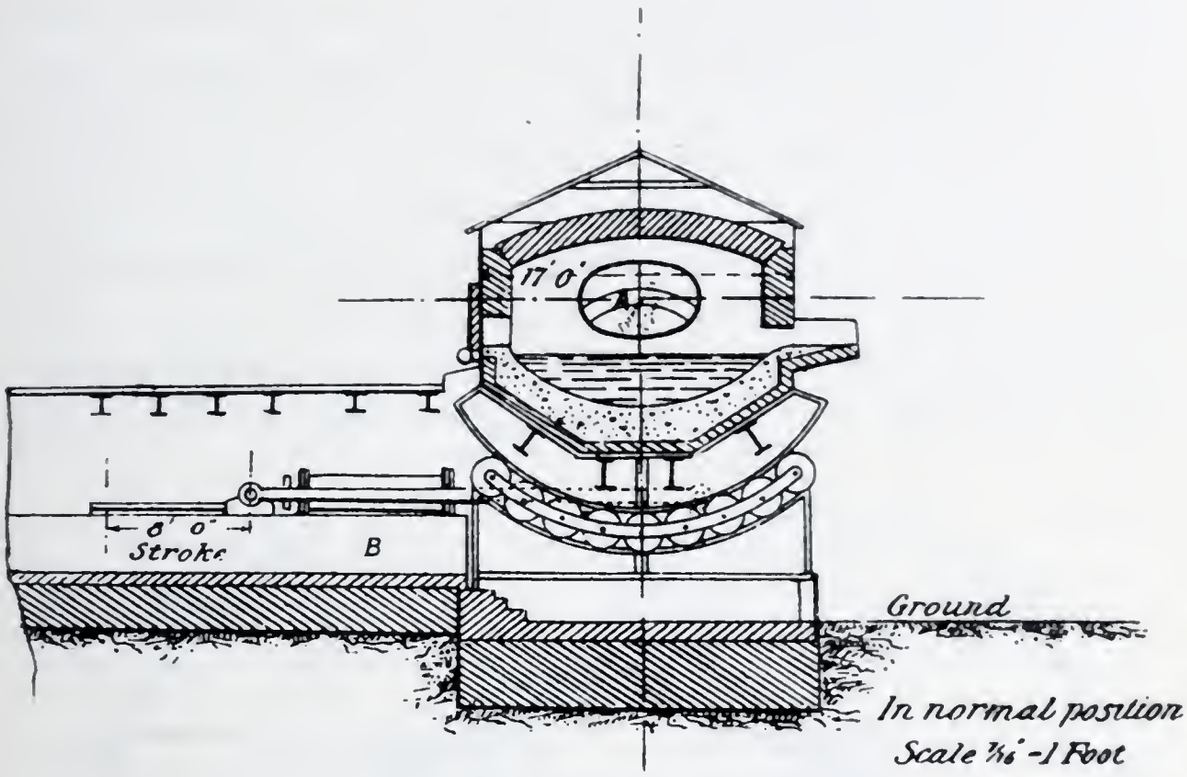


FIG. 9.

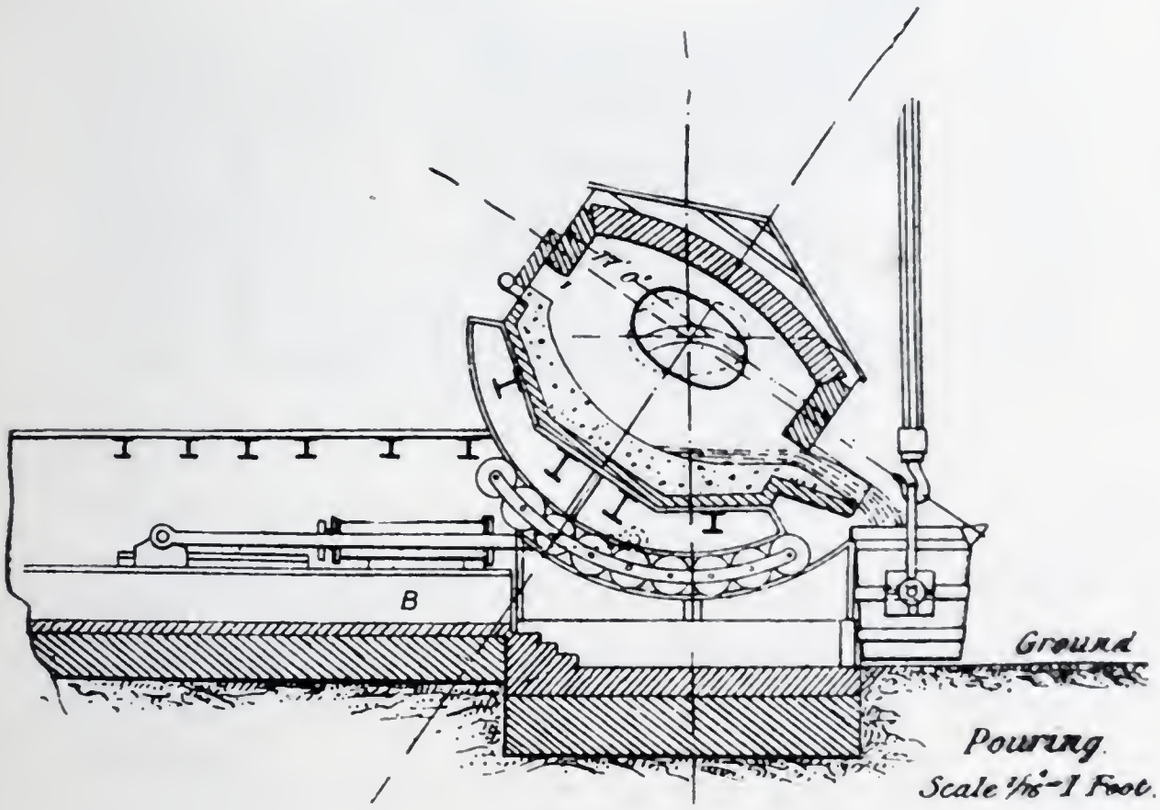


FIG. 10.

Campbell Tilting Furnace.

quartered water-sealed drum, the hollow or water-cooled disc types by Campbell, Wellman, Hyatt and others, Wailes', Hall's Mills' and Tuerk's water-sealed, Ramsbottom's and Fisher's modifications of Siemens' valves, Wailes' and Forter's water-controlled and many others. All have certain advantages, none are perfect. Figs. 12, 13 and 14 illustrate the three first mentioned which are commonly used.

Besides the so-called stationary furnaces—those just described and which are the ordinary type—there are in opera-

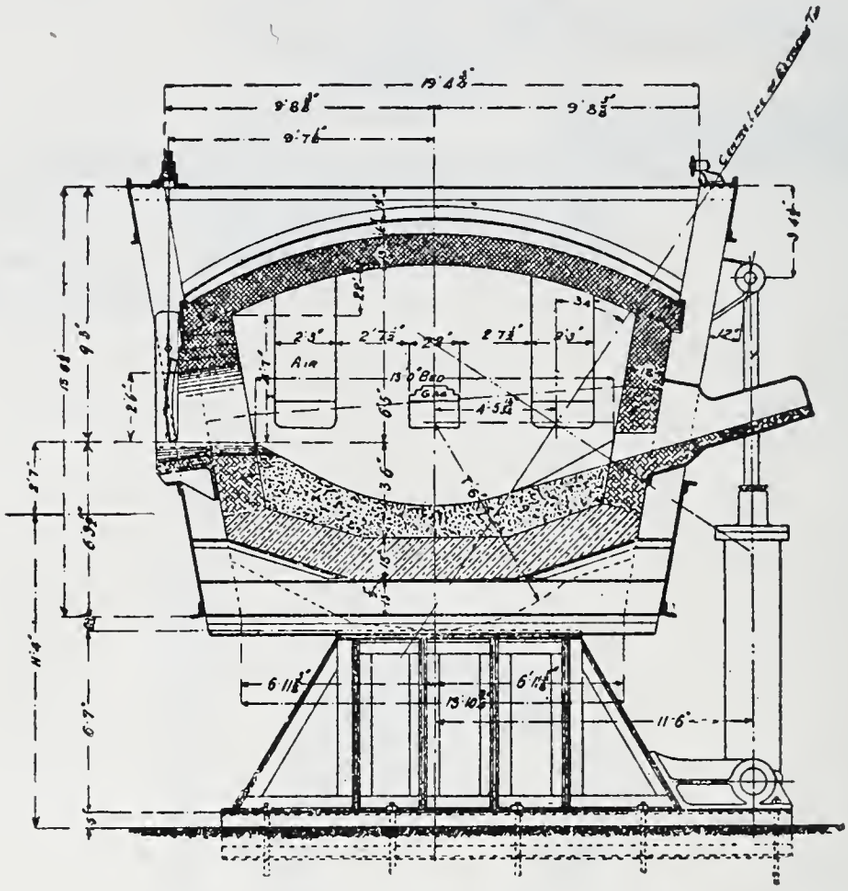


Fig. 11. Wellman Tilting Furnace.

tion quite a number of furnaces with revolving hearths. Such furnaces have the advantage that the steel can be poured out at any desired moment and in any desired quantity without the obnoxious operation of opening, cleaning and careful closing of the tap-hole. There are two distinct types of such tilting furnaces, the Campbell type and the Wellman type. In the first one, Figs. 9 and 10, the hearth, supported on rollers, revolves around its center line, coinciding with the center line through the ports. The gas and air connections are such that the gas does not have to be shut off in any position

of the hearth. In the second one, Fig. 11, the hearth is pulled out of the center line around a pivot under the hearth and outside the center line. When this furnace is tilted, the gas has to be shut off entirely.

Much has been said pro and con in the discussion of the merits of these tilting furnaces, the main objection being the high first cost, the difficulty of maintaining the roofs, etc., and the accessibility of cold air through the more or less defective joint

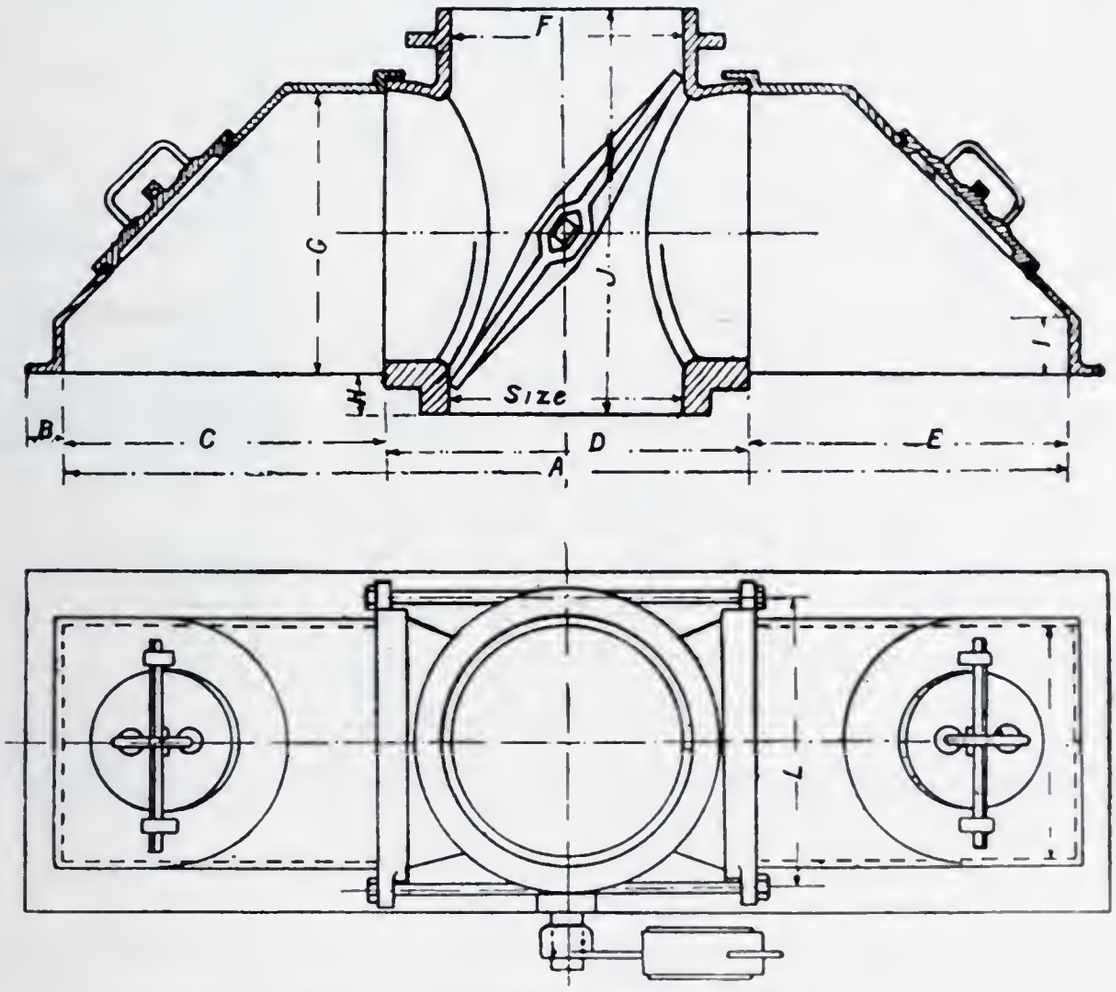


Fig. 12. Siemens Reversing Valve.

between the stationary and movable parts. At the Pennsylvania Steel Company, Jones & Laughlin's Steel Works in Pittsburgh, and several other plants in the United States, they seem to be well thought of.

The open-hearth furnaces, especially the ones with basic lining, are becoming more and more the main producers of steel, especially since the use of fluid pig metal taken from the blast furnace or mixer has been found practicable. The fuel commonly

used is producer gas, in the Pittsburgh district natural gas, and in some works petroleum, crude or semi-refined, or even as in Russia and Austria coal oil residue. According to the quality of raw material to be melted and the quality of the finished steel desired, a good basic furnace of about 35-ton capacity should produce ingots with about 600 to 650 pounds of fair gas coal per gross ton of ingot. This figure can and has been materially improved upon. Acid furnaces of course should require less fuel, so will basic furnaces with a minimal lime charge melting clean good raw material and producing ordinary qualities of steel. However, there

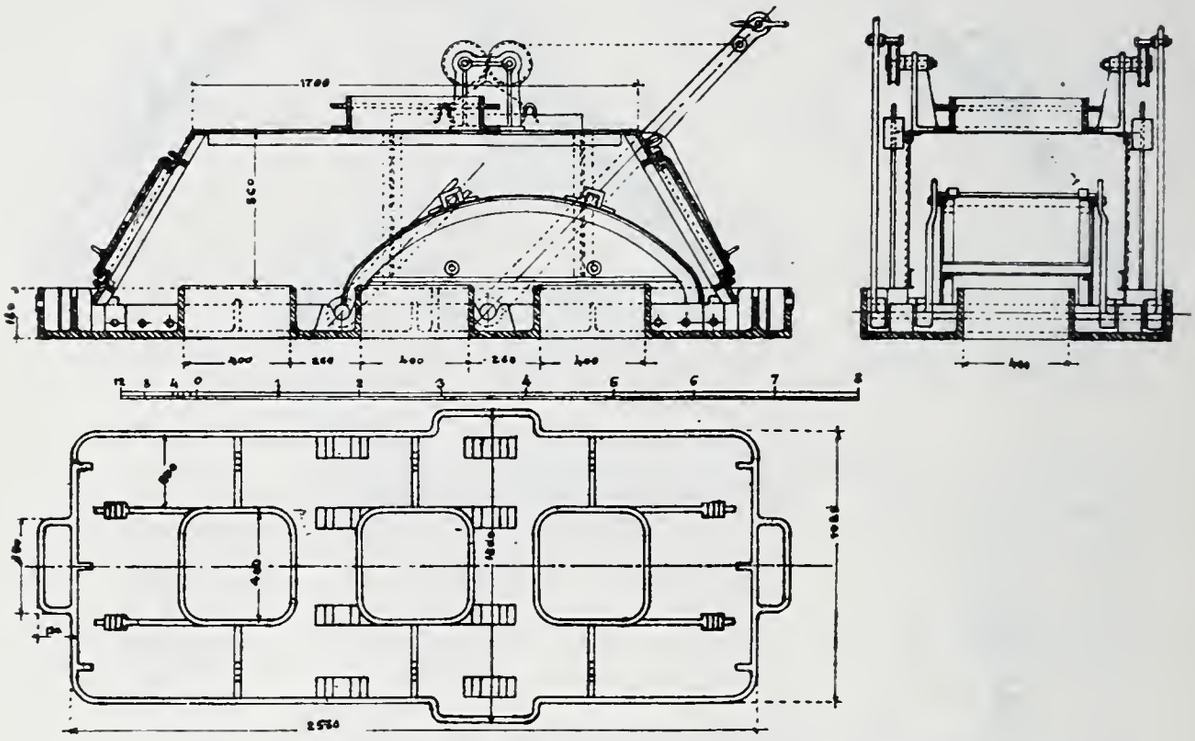


Fig. 13. Forter Water Seal Reversing Valve.

are many furnaces in operation which consume considerably larger amounts of coal. With natural gas good practice shows a consumption of about 5,600 to 6,000 cubic feet per ton. With coal oil the figures obtainable vary considerably, though about 45 gallons per ton of steel ingots seems to represent a fair average. A good 25-ton basic furnace should make about 17 to 18 heats per week of six days, a 50-ton one about 14 to 15, with cold but fair raw materials.

The usual practice is to charge the furnace with cold materials, or at least cold steel scrap, with limestone additions in the basic furnace, and fluid pig iron and, when the steel is finished,

to tap the whole charge into a ladle from which it is poured into the moulds. The moulds for ingots are either filled from the top, when of large capacity and for ordinary purposes—"top cast" —or from the bottom in groups, when of smaller size and for special purposes—"bottom-cast."

Of late the use of fluid blast furnace metal has brought about some special processes like the duplex process, a combination of

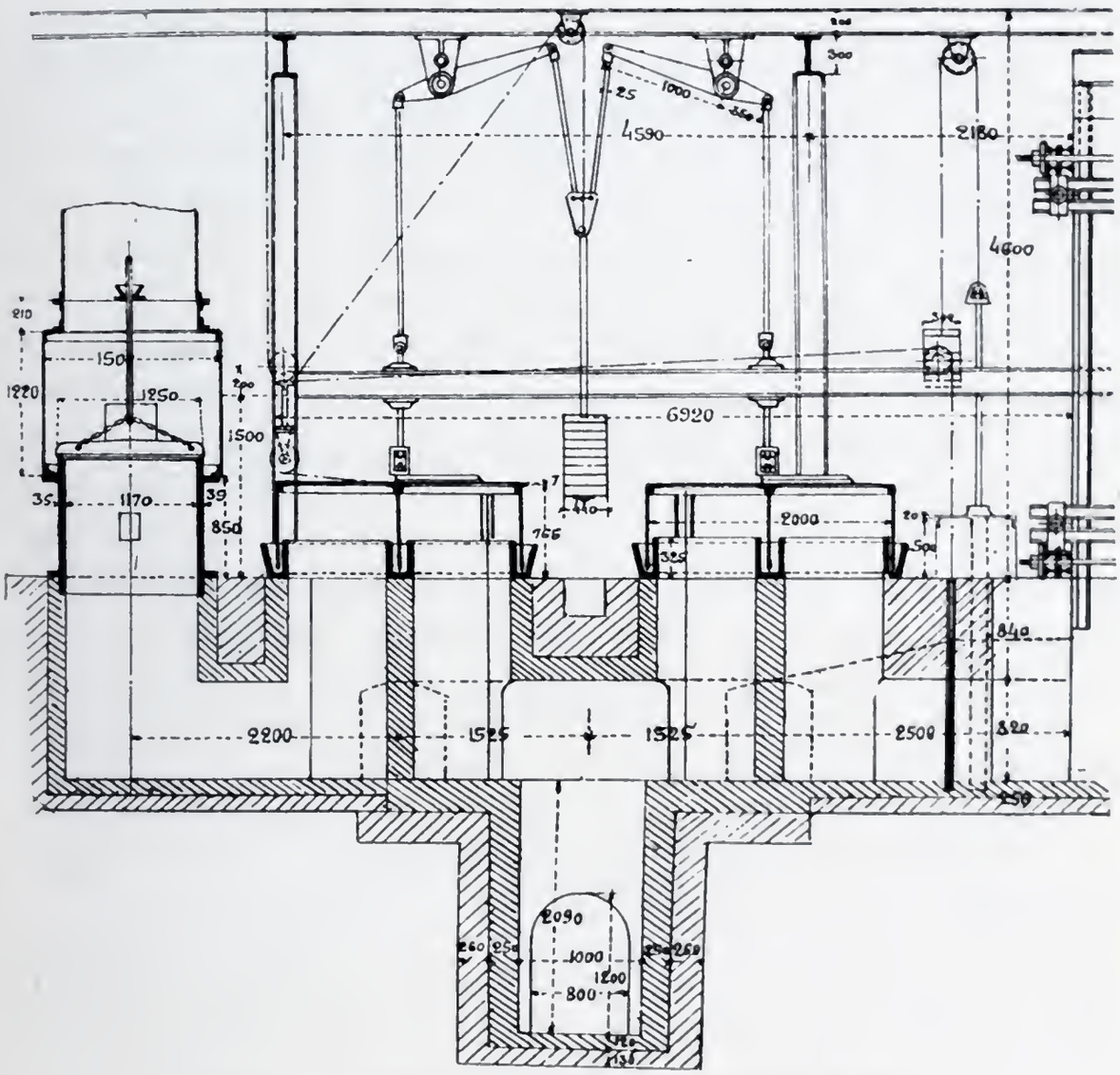


FIG. 14. Watersealed Drum Reversing Valve.

acid Bessemer fining and basic open-hearth finishing work, and the Bertrand-Thiel process—carried out by a combination of a primary preliminary washing basic furnace and a secondary finishing furnace, also basic. The first mentioned process was advocated by me for the working of the irons of the Birmingham, Ala., district some fifteen years ago, and is now finally in successful use at

the Ensley, Ala., Steel Works, and its application in this district may eventually prove to be successful, too, notwithstanding the adverse criticism of great authorities The second process is so far not applied in the United States, but could be successful especially by the use of tilting furnaces and a ladle for transferring the partly purified metal from one furnace to the other. It is at present in use at the steel works in Hoesch, Germany, and Kladno, Austria.

The Monell process, partly in use in the different Carnegie plants, consists in charging in a basic open-hearth furnace, limestone and a relatively large quantity of ore, heating these and then charging molten pig metal from a mixer or direct from the blast furnace. The temperature of the resulting mixture must be low enough to insure rapid oxidation of phosphorus. The slag formed rises and is drawn off at a cinder notch, taking with it practically all the phosphorus and silicon. Within an hour after charging the molten pig, the bath is free from phosphorus, silicon and manganese and the bulk of the slag containing these impurities is removed while the carbon in the bath is still high. The heat is then finished as usual and finally tapped when the carbon has reached the desired point. The Monell process was the logical outcome of experiments made in 1898 for the use of large percentages of fluid pig metal. It is in use also in Donawitz, Austria, and in a Russian steel works.

The Talbot continuous process requires the use of a basic lined tilting furnace of large capacity (75 to 100 tons or more). The furnace is charged Sunday evening with about 50 per cent. scrap and 50 per cent. pig and this first heat or filling is worked down to steel in the usual way. When the bath is good finished steel, about one-third of it is poured off into a ladle and cast into ingots. No slag is run off with the steel. After tapping off this third of the charge, oxide of iron is added to the slag and as soon as this is melted, about 20 tons of molten metal are run in to replace the steel tapped off. Immediately a violent reaction takes place, large volumes of CO gas are given off, which ignite and burn with intense flame, the heat of which partly raises the temperature of the bath and partly is absorbed by the regenerators. After the reac-

tion has ceased, *i. e.* about 15 to 20 minutes, the slag which is now almost deprived of iron oxide, is partly poured off and the bath is worked down into finished steel by fresh additions of iron ore and lime. When the bath is ready, one-third or about 20 tons of steel is cast, fresh slag additions are made, and another 20 tons of molten pig metal added as before. These operations are continued during the whole of the week, the furnace being completely emptied only on Saturday. This process is in use in Frodingham and Cardiff, England, and at the Jones & Laughlin Steel Works in Pittsburgh, who lately have added several more tilting furnaces for the making of steel by the Talbot process. A modification of the Talbot process is being applied at the B. Hantke Steel Works in Czenstochau, Russia, by Surzicks, a stationary furnace being supplied with two tap-holes, of whch the upper one serves for letting out one-third of the contents of the furnace, the lower one for the complete emptying. Perhaps the use of a third tap-hole, still higher up, for the removal of slag would be an improvement, and thus the Monell and Talbot processes could be combined.

Before I finish I want to call your attention to the relatively greater number of heats per day that are taken out of some foreign furnaces. In Germany I have seen furnaces that make a heat in four hours from tap to tap. In a furnace that we would consider of thirty tons capacity, they will make only fifteen tons; and then they tap twice as often. So that instead of tapping three times for thirty tons they will tap six times for fifteen tons. And for what is a seemingly small hearth they have tremendous regenerators. They have a regenerator for a fifteen ton furnace that we would consider ample for a thirty ton furnace in the United States. And you will at once see the effect of this practice.

DISCUSSION.

Mr. Ralph Crooker, Jr., Mem. Eng. So. W. Pa.—It may be of interest to state that many years ago, one Josiah Marshal Heath invented and patented in England what is now generally known as the open hearth steel process. He did not make a success of it, because he was unable to attain a high enough temperature to keep the wrought iron in a molten state.

Then came the invention of the Bessemer process, which was anything but a success until Mushet's invention of the triple compound of iron, carbon and manganese enabled it to revolutionize the iron and steel business. Anybody who knows the difference between a heat of blown Bessemer steel before and after the manganese addition can realize the importance of Mushet's invention. If Heath had been able to get the required temperature, he would then have encountered the same difficulty that confronted Bessemer, and would have required, as well, the Mushet addition to have made good steel.

The invention of the Siemen's regenerative gas furnace made it possible to obtain the temperature necessary to put Heath's process into practical use and a man named Martin quickly took out a patent, which was simply the addition of Mushet's invention to Heath's process [using the Siemen's furnace for melting] something which was clearly anticipated by the state of the art at the time, and introduced the process under the name of the Siemen's-Martin process. Many of the iron masters of that day disputed the right of Martin to the claims he made, and called it the "Open Hearth" process instead, giving it that name in contra-distinction to the crucible steel process, in which the metal is melted in covered pots, while in the new process, it was made on the uncovered hearth of the furnace.

There were many patent law suits growing out of the views held by many in regard to the validity of the Martin patents. Martin's name is now hardly remembered in connection with the process, at least in this country, where it is now known only as the Open Hearth process.

Mr. H. C. Babbitt, Mem. Eng. So. W. Pa.—There was a great deal of discussion whether it should be called the Martin-Siemen's or the Siemen's-Martin process.

Mr. G. E. Flanagan, Mem. Eng. So. W. Pa.—Referring to the former use of old rails for binding stays, Mr. Luetscher might have dwelt at greater length upon the somewhat elaborate system of binding for the modern furnace, in which much ingenuity is displayed in the design of massive I beam framing so disposed as to resist changes in form due to great variations of temperature.

Some furnace builders lay considerable stress upon having

the roof constructed so as to avoid continuous joints lengthwise of the furnace, as with the joints broken the roof presents greater resistance to the cutting action of the flame.

When placing the fire-brick lining in steel stacks, the bricks are frequently laid in a continuous spiral, in place of a succession of rings, one above another. This method obviates the necessity of chipping a brick to complete the course as each ring is laid, in case the length of the bricks is not exactly right to form a circle with a given number.

I would like to ask Mr. Luetscher whether or not he has experienced much trouble in the use of water-sealed valves due to the pressure of steam in the furnace flues from the evaporation of the water used to form the valve seal.

Mr. G. L. Luetscher—The roofs of the furnaces are built of straight arches. It is not possible to get a good job by interlocking. It is far preferable to have each arch independent, then if one arch drops they don't all drop, while if the roof has all the bricks tied together you are liable to have a large part of the roof drop from a small failure. The better roof is a 13 inch roof. Roofs with 13 inch bricks have lasted 750 heats with basic furnaces.

The flames cut the walls, the flames and chemical action together form the slag. You can fix that up though when the furnace is in operation. In a basic furnace we sometimes build the backwall of dolomite or magnesite up to the roof. But they generally play out all over. The checkers get filled with dust and the roof gets out of shape and by that time the walls will be giving out too.

As to water from the valves, it used to be when the water-sealed valve first came out they thought they had to keep the inside hood sprinkled with water. But under the present construction you can keep water running so as to keep it cool and with only a very little steam. I never found much trouble as long as we take the water off the "bonnet" inside.

The warping does not always come from the incoming gas, it comes often from the outgoing waste gases. By shutting off the air the waste gas will burn down in the checkers. And furthermore, if the gas is of the wrong composition, especially if it is

high in hydrogen, the hydrogen cannot burn on the hearth because in the process of combustion it would form steam, and steam cannot exist at that high temperature. It will only burn at the lower temperature down in the checkers.

The stack construction I never paid particular attention to. I have built stacks with independent rings and with spiral rings. I generally leave that to the taste of the bricklayer. One way lasts as well as the other. I have never had any trouble with stacks whether they were laid spiral or independent. It is simply a question of the way the bricklayer will do it cheapest.

Mr. H. H. Anderson, Mem. Eng. So. W. Pa.—In the roofs of furnaces have you any trouble with the spawling of silica bricks?

Mr. G. L. Luetscher—A good silica brick will not spawl if it is heated right. If a silica brick spawls, it is either a case of a poor brick or a poor furnaceman.

Mr. A. Stucki, Mem. Eng. So. W. Pa.—What is the proportionate use in this country of the basic and the acid processes, and what proportion of acid steel is used for steel castings?

Mr. G. L. Luetscher—High authorities may be found who claim that acid steel is better for everything. I believe basic steel can be made of as good quality for almost any purpose whatever as acid. It is only a question of how you make it.

However, when you come to higher carbons, the difficulty of finishing combined with the difficulty in removing the phosphorus and other impurities begins to show, and it would be very difficult to make high carbon basic steel of accurate composition. Otherwise there is no reason why basic steel should not be as good as acid. I have made basic steel with $1\frac{1}{4}\%$ of carbon that was declared by users fully as good as any acid. I have also made basic steel castings that were fully as good as acid steel castings made by myself, so I have no prejudice in this matter either way.

Basic steel can be made cheaper in large quantities as it only requires a few raw materials, and the raw materials can be obtained more easily. Acid steel requires raw materials of a given composition and generally of a higher price. One use for acid steel that has been found is seemingly contradictory to what I say, and that is for sheet bar for tin plate. It is known that if

sheet bar is too pure the sheets will stick together when they double or quadruple them in tin mills, so you want them a little higher in phosphorus. In the basic open hearth furnace it is much easier to remove all the phosphorus than to remove a certain part, and you never have as sure a result as you do in the acid process, where you cannot remove any phosphorus. Otherwise, for my part I prefer basic boiler plate to an acid boiler plate.

Mr. H. H. Anderson—I think it is a good indication of the success of the process that the largest corporation we have, has adopted the basic furnace.

Has there been any improvement lately in the casting of steel, say of about 70 carbon in large ingots weighing 6 or 7 tons? It seems difficult to get an ingot of that size free from checks or porous places, which in rolling shows as slight imperfections or laminations on the surface.

Mr. G. L. Luetscher—That checking you speak of is chiefly due to the contraction of large masses. The larger the ingot the larger, of course, the actual amount of contraction, and if the ingot does not release itself readily from the mould it will tear apart. That is not due to the process itself. You can get the same result from the acid process ingots. It is one of the reasons why the larger plate manufacturers have all adopted the method of first slabbing the ingots, then reheating the slabs and putting them in the plate mill, just to avoid or overcome all these surface defects. That is one of the tricks of the trade, to make ingot plates rolling direct from the ingot instead of making slabs out of it.

Mr. R. A. McDonald, Mem. Eng. So. W. Pa.—I agree that basic steel properly made is equal, if not superior, to acid steel for almost all purposes. But I would like to cite the point regarding nickel steel. A few years ago nickel steel was supposed to be made only in acid furnaces; to-day it is made in basic furnaces. Statistics show that the acid furnace is going out of existence, as far as merchant steel is concerned. It will only be a question of time till our engineers have forgotten that they ever used acid steel. There may be some improvement in the near future in steel, but I think that the basic steel all the way through for almost all purposes will supplant the acid product.

Mr. G. L. Luetscher—It is a question of local costs whether the basic steel will supplant the acid. It may be possible that in some localities the raw materials can be obtained of such a suitable purity that it is not necessary to go through the more expensive process of melting in a basic furnace. And for certain purposes, as I said before, it may be even better to use acid steel, because it may be obtained with a certain fixed amount of impurities.

Mr. Samuel Diescher, Mem. Eng. So. W. Pa.—Some time ago I had occasion to examine a piston rod that broke in service and in order to find of what material it was made, I had an analysis made of it. The chemist reported that the rod was made of basic steel. I asked him what difference it makes whether steel is basic or acid, and he said: that owing to the stickiness of basic slag, this latter is not so thoroughly eliminated from the steel during rolling, etc., as is the case with the acid process having a more liquid slag, and that slag in basic steel may lie in any direction with a bar; transversely as well as longitudinally. If this theory is correct then there is certainly a risk involved in the use of basic steel.

Mr. H. C. Babbitt—I would like to ask Mr. Diescher if that piston was forged or was rolled.

Mr. Samuel Diescher—It was rolled.

Mr. H. C. Babbitt—If it was rolled and there was any slag in there it would form laminations longitudinally.

Mr. Samuel Diescher—That would be natural in wrought iron, owing to its fibrous structure in which the slag lies between the fibres, and, therefore, does not affect the tensile strength of a bar, but if slag lies in any other direction, it must necessarily have a serious effect upon the tensile strength of the material.

Mr. G. L. Luetscher—There is no more slag in a basic steel ingot than in an acid steel ingot. You can make pure steel in a basic furnace as well as you can in an acid furnace. The most kicking on basic steel came when it was first made, and it was due to lack of experience of the maker rather than to the metal itself. You can make as good material for forgings and all structural purposes, boiler plates, etc., in a basic furnace as in an acid furnace. As to the slag content, your chemist probably was mistaken.

MR. H. C. BABBITT—I had the pleasure of being associated as a chemist with one of the first basic steel makers, and to make a great many determinations of slag in steel. I almost invariably found less slag and oxides in basic steel than I did in acid. And that corroborates Mr. Luetscher in the matter of steel castings. The finest steel castings I have ever seen were made by the basic process, and I think the reason why acid steel is specified to-day is because people do not know what they are specifying.

MR. L. C. MOORE, Mem. Eng. So. W. Pa.—Why is it American makers of steel do not make as good a grade of stock for wire as they do abroad? Basic open hearth steel bought abroad will show a loss of less than 3%, while no American manufacturer will come within 10%. It is what we call high grade steel for wire, dress stays, etc.

MR. G. L. LUETSCHER—I have frequently found that the customer does not consume large enough quantities to justify anybody experimenting to make the proper grade. Moreover, the tendency in this country is for large furnaces and for large product. The finer and better qualities are made in smaller furnaces and invariably bottom cast. I believe that a works built for no other purpose than to make such specialties would pay well, if properly handled from a scientific standpoint. The same metal could be made here as in Europe, in fact better, for we have natural gas and several other advantages. That steel you refer to comes from Sweden, doesn't it?

MR. L. C. MOORE—No, sir, about 20% from Scotland, about 60% from England and the remaining 20% divided between Germany and Sweden.

I believe Mr. Luetscher is right, though, for some fifteen years ago the people with whom I was connected bought 100 tons of billets from the Bethlehem Company and they made very fine stock; but the Bethlehem people never cared to duplicate it. And I believe also, as he says, that if some firm would start a plant with a capacity of 50 tons a day, and keep it down to that, they could make a good thing out of it. English stock to-day is worth about 2½ times what our low carbon Bessemer wire rods are.

Mr. H. C. Babbitt—I have had the same experience. We bought billets from the Bethlehem Company to make corset steels, and they didn't care to take a second order. It was too much trouble.

Mr. L. C. Moore—Cannot this higher carbon steel, say 50 to 90 carbon, be made in a 50 ton furnace, or must it be made in a small 10 or 15 ton furnace?

Mr. G. L. Luetscher—It is made in large furnaces. There are practical difficulties in the way of large furnaces making steel of as good quality as smaller furnaces, say of 15 tons. Especially in pouring and the final additions in the shape of silicon pig iron and spiegel, the quantity gets very large with a 50 ton charge, and when you put that in you do not get as accurate results as you do with a small furnace. I believe such steel ought to be poured in small moulds, and generally people that have 50 ton furnaces are not likely to pour into 1500 lb. ingots.

METHODS OF EXPANSION OF RAILWAY BRIDGES.*

BY FRANCIS S. RICE,
Member Engineers' Society of Western Pennsylvania.

My only purpose will be briefly to outline a few of the simpler and plainer principles of expansion in railway bridges, and I shall probably only repeat what all of you already know. At the same time we may place data before us upon which we may establish some sort of a quiz or talk.

In regard to the question of expansion in railway bridges, the question resolves itself into a practical one rather than one of theory. On the other hand it is treated in the specifications on the part of railways and generally in the practical designing of bridges almost wholly from a theoretical standpoint. I shall have occasion to refer to some points of difference between this theoretical standpoint and the practical standpoint later on.

When the necessity of making provision for expansion was first recognized it was naturally treated as now by providing the ordinary type of one plane surface sliding upon another. This simple design is used generally for stringers, and for plate girders of moderate span. Most of the railways confine this type of expansion design to spans of not over 75 feet.

As spans became longer, heavier weights must be provided for, and as this method of providing for the expansion was not considered sufficient, more skill was employed in the design, and the next natural type was through the introduction of rollers, between the two plane plates. Both of these types were modified and improved by the addition of a tongue and groove, thus providing against transverse motion without causing friction or binding on the anchor bolts.

*Meeting Structural Section, January 24, 1905.

The roller type was provided with side bars acting as spacers, and later much ingenuity has been shown in the endeavor to make them proof against the admission of snow, dirt and water.

When much heavier spans were designed, it was considered necessary to have larger rollers, and there was objection to their weight and size. This objection was met by the design of the segmental form of roller, which was first used by German Engineers so far as we have records.

This covers nearly the whole practice of ordinary expansion bearings in railway bridges. These types are often modified more or less. For instance, some of the later railroad specifications require that dust guards shall be placed on the four sides of roller bearings, and shall be held in place with tap bolts so that they can be removed and the rollers cleaned and oiled.

The best known determination of the coefficient of expansion in steel for one degree of Fahrenheit, expressed in terms of the length, is that ascertained by the United States Government through a series of careful experiments at Watertown Arsenal about 1887 and expressed decimally is 0.000,006,466 or $1 \div 154,655$. For a variation in temperature of 150°F. this amounts to $1\frac{1}{8}$ inches in 100 feet.

Railway specifications generally call for a rate of expansion of 1 inch in 100 feet, which is very nearly this amount. Stated in another way the expansion amounts to one inch in 85.9 feet. Taking the modulus of elasticity of steel at 29,000,000 lbs., which is the commonly accepted coefficient, and calculating the amount of actual distortion in the steel occasioned by this 150° of temperature variation, and we find that the amount of stress in steel, required to produce an equal distortion, would be 28,130 lbs. per square inch. Stated in a different way, the amount of elongation or contraction occasioned in the lower chord or any other member of a steel structure through a variation of 150 degrees F. is the same as that occasioned in the same member by a strain of 28,130 lbs. per square inch, and this is very near the elastic limit of ordinary structural steel.

Now as regards certain factors of friction: Roller friction is a very uncertain quantity, and depends so entirely on the finish of the surface of both the beds and the rollers themselves that it is difficult to give any average statement for it. A fair average coefficient would be 0.002 of the weight, which is the stress required to move a body under ordinary rolling friction with such conditions as originally exist in a roller shoe. The sliding friction such as would be occasioned in the first type of shoe, ranges from .07 to 0.11 of the weight for the start, and after the start is made it comes down to as low as 0.004. In other words this sliding friction after the shoe is started is just about twice as much as the rolling friction, if each were in perfect condition.

In regard to the effect of the pressure per square inch on sliding friction, I might say that up to a reasonable limit the pressure per square inch has no effect upon the percentage of weight which would overcome that friction. This reasonable limit is about 500 or 600 lbs. per square inch. If you should make a shoe of one-half the square area of another shoe, and put them both under the same weight, one would be weighted with twice the pressure per square inch that the other would, but the force required to move them would be the same. Prof. Thurston is authority for the statement that in the pivots of some center bearing draw bridges the amount of this sliding friction amounts to as high as 9,000 lbs. per square inch. That seems to me a very high unit stress and I cannot think that it has been intentionally employed in designing. However, the New York Central in their specifications specify that bearings on phosphor-bronze can be employed at an unit stress of 5,000 lbs. per square inch.

There seems to be some difference between the theoretical and practical standpoints of this expansion question. Theoretically the best results should be obtained from rolling shoes. Yet I have seen numbers of good engineers, practical men who are acquainted with these things, give a smile, and sometimes a broad one, when the subject of rollers and roller shoes was mentioned. It seems to be a kind of joke among them, that these roller shoes are very nice to put in the draw-

ing, but that after they have been in the bridge five or six months they are rusted and the bridge never moves. Whether it does move or not the consequences might not be serious in an ordinary span; but for a long span the effect would be worse.

I have tried to approximate the effect by the statement that a stress of 28,130 lbs. per square inch is caused by a change of 150 Fahrenheit. That seems to be a point where theory and practice conflict, for otherwise since it is well known that the shoes of many bridges do not move, from the above considerations they should pull over their piers at least twice a year.

Just to draw a little discussion I may say that it is my opinion that we are wrong in adopting the roller shoe. I think we had better go back to the plane or sliding shoe. The difference in the amount of resistance or friction between the sliding and the roller shoe is very small, and is not to be compared with the benefit gained from the eventual maintenance of the feature of expansion in all bridges. I take that ground from the fact that the roller shoe, while efficient when first placed, is impossible to maintain practically. The shoe is below the railroad track in all cases. It is subject to the varying eddies and currents of wind and storm, and catches dust from every passing train; sand and ballast gather around the rollers, the accumulation draws and retains moisture, rust follows, and the shoe is stuck fast, and little is or can be done to prevent that condition. I hold that the difficulties of preventing that condition are so serious that we had better go back to the old plane sliding shoe. It would be easy to design a plane sliding shoe for any span which might have a phosphor-bronze bearing for one of the surfaces, and which would be so tight that if properly lubricated it would be effectually sealed and could be practically maintained in a working condition.

DISCUSSION.

Mr. Willis Whited, Member Eng. So. W. Pa.—I like Mr. Rice's idea of flat bearings, but almost any kind of bronze would do as well as phosphor-bronze. Instead of

oiling it, give both surfaces a coating of a mixture of plumbago and tallow with just enough oil added to make a paste; it will not dry, decay or evaporate, and it reduces friction as much as can be done practically by any other means and requires no subsequent attention.

It is a fact that draw bridges to-day often have five, six, or eight thousand pounds pressure per square inch on their bearings and they will stand it all right if the bearing is well fitted and lubricated with something like plumbago that will not squeeze out easily.

Mr. G. H. Danforth, Mem. Eng. So. W. Pa.—The firm I was with in 1896 put in a drawbridge on the New York & Long Branch Railroad.

It was a center bearing bridge having two phosphor-bronze discs, with a steel plate between. These discs were figured for about 5,000 pounds per square inch, and I think got fully that load.

On account of faulty design, it could not be lubricated very well, as the oil could run out as fast as it was poured in.

The bridge was put in in the spring before navigation opened and during the summer the railroad had trouble with it. In the fall I was one of two men to go down there and with the assistance of a section crew, jack the bridge up on a Sunday for an examination. The discs were found in good condition, in spite of the loading, and of the fact that the lubrication had been defective.

Mr. T. J. Wilkerson, Mem. Eng. So. W. Pa.—I have been advised by reliable authority that on the Memphis bridge Mr. Morrison used segmental rollers and placed on one set of rollers a vernier to enable him to ascertain the elongation produced by a heavy train passing over the bridge. When the load passed over, the vernier did not show any elongation; there was no doubt some elongation and it was doubtless taken up by the piers springing.

Referring to Mr. Rice's unit strains of 28,130 lbs. per square inch caused by a temperature change of 150 degrees. If we assume that the change of temperature is 100 degrees, which is sufficient for most localities, we will get a unit strain

of about 18,500 lbs. per square inch, which added to 12,500 pounds per square inch, the unit strain usually allowed for railroad bridges, we get 31,000 lbs. per square inch, which is less than the elastic limit of good medium steel, hence we would be unable to tell if our bridge has been subjected to higher unit strains than it was designed to carry.

From all evidence I have been able to obtain it appears that very few rollers ever move after they have been in place sufficiently long to rust.

Mr. L. P. Blum, Mem. Eng. So. W. Pa.—Has anyone ever observed how much movement there actually is in a long truss and a difference in temperature of 90 degrees? Is it anything near what the theoretical figures make it? Would not some portion of the contraction or expansion be taken up in the joints?

Mr. F. S. Rice—Mr. Wilkerson's remarks about Mr. Morrison's bridge at Memphis calls to my mind a further case of Mr. Morrison's practice. Mr. Morrison designed a bridge for the O. R. & N. R. R. over the Columbia river at Portland, and it has quite a long draw span, probably 250 feet, with several approach spans of equal length. The foundations of the draw spans and the approach spans are iron tubular piers filled with concrete which are something like twelve feet in diameter set on piles extending down into the alluvial bottom a considerable distance. Mr. Morrison put in these spans, approaches and draw span without any expansion whatever. Any serious expansion there would seriously interfere with the working of the draw span. I made careful inquiry of the bridge tender and was informed that they had never had any serious trouble with the draw span on that bridge, although any serious expansion in the structure would certainly pinch the draw span and make it hard to operate.

CUSHIONED FLOOR BEDS FOR RAILROAD BRIDGES.*

BY E. K. MORSE,
Member Engineers' Society of Western Pennsylvania.

I regret that I cannot take you back any farther in the history of bridge construction, but my personal experience only began in 1876. Up to the present time the style of construction in the floor system has not varied in any particular from what it was when I first entered the field. The only difference is that we have heavier loads, more sections and some rivets thrown in for impact.

It may seem unnecessary, but it has a pertinent relation that we should take the load and analyze every step of it. The load coming from an engine or a following load comes on to the rails, from the rails to the ties, the ties to the stringers, the stringers to the beams, and the beams to the members of the truss and thence to the masonry. It is plain to be seen that with a moving load passing over a structure, the stringers cannot possibly escape the moving load; they must not only receive the full load, but get its maximum strain, whereas that same load on the trusses may only strain them up to a fraction of their capacity.

On the other parts of the construction of our modern bridges we have reached a very high state of perfection, and that is proven conclusively in the action of our structures as fabricated, designed and built to-day. They are giving perfect satisfaction, and that is brought about in our main members by the fact that away back early in the 80's we had testing machines that would test full-sized members to destruction. The Athens shop took an eye bar in 1888 and pulled it up to two million pounds before it broke.

Now we have had nothing in the design or construction of floor system that allows us to do anything more than simply add section. I regret that possibly only one out of ten of the bridge

*Meeting of Structural Section, January 24, 1905.

engineers and designers, some of them eminent, whom I have met have ever been on an engine. They don't know what an engine load is on a bridge, how it travels, what the action is, its pounding, rocking, etc. And I regret that every engineer does not have a little taste of erection and have to realize what the enormous stress is from an engine load moving at a rapid speed over a bridge. It is only the fraction of a second in passing over these members. Consequently we do get impact. I have been under an old bridge hanging onto the laterals, when I was almost frightened enough to drop off.

We have had many attempts in the last 15 years in the construction of the floor system to meet the conditions which I wish especially to touch on this evening, but none have been satisfactory. In riding on an engine there is a good deal of rocking and a good deal of elasticity in the road-bed. But the moment you strike a bridge it comes just as if you were striking that bridge fair and square end on. There is no easy gliding over it, it is a distinct blow. A man who is not used to it, riding in a cab, will almost rise to his feet. The reason for it is this. You watch an engine, especially if it is going slow so that you can read the deflections a little more clearly, and it is surprising how much elasticity there is in the rail and tie and the whole road-bed, often to such an extent that on many roads the engine is always riding up hill because there is always a wave in front of it. But the moment you come to a bridge, what is the construction? We securely notch and bolt down the guard rail to the ties and the ties are bolted and clamped just as hard as we know how to the stringers, and the rail spiked on to a plate and that plate resting over the ties, so that it is just as taut as we know how to make it. The approaching engine and following load must, therefore, pass immediately from the elastic surface road-bed on to the bridge floor so designed that we arrive at the greatest amount of impact that our ingenuity can bring about. There is no way of increasing it that I know of.

I believe at the present time we have a solution, but not in concrete, which is only approaching a rock foundation for the ties. It has always added greatly to the dead load of the bridge and has never yet made a nice riding structure. We put ballast

over it, but we have a rock under the ballast, concrete is simply a rock, there is no give or take and it is really no benefit to the riding of a track over the structure. It has simply added enormously to the cost of construction.

About five years ago the first granulated cinder that I had anything to do with was made by Mr. Henry A. Laughlin at the Eliza Blast Furnaces, Jones & Laughlin Steel Co. The cinder as it comes from the furnace is passed over a jet of water and drops into a vat. That is granulated cinder. When you are making slag sand you break down the horizontal jet with a vertical one and it drops down in the vat. But to-night I am treating simply of the granulated cinder. We were reconstructing the present furnaces and were very much annoyed to get any kind of a fill, and the question came up, Couldn't we use granulated cinder? It was so light it seemed out of the question. But there was no choice and no time to lose and it was adopted. The first I ever saw used was a fill I made between Second avenue and the stock house averaging 50 ft. wide, as high as 30 ft., and 1200 ft. long. I expected when we took the tracks off the wooden trestle we had filled through, and placed them where we wanted them, they would simply go out of sight. But to my great surprise when we took off the wooden stringers and caps and placed the tracks where desired, there was hardly any appreciable settling. The first year they were surfaced a little, but nothing like what would have been the case had ordinary clay or refuse from the mills been used.

It naturally set me to thinking. This loose, light, fluffy stuff, it will float on water, you can crush it in your hands, there is nothing to it. You would think it would be about as miserable stuff as could possibly be used for any kind of railroad construction. At that time I was finishing up the hot metal bridge for the same firm. A discussion came up as to using the style of construction that was adopted by the Carnegie Steel Company at Port Perry and the Carrie Furnace later, that was the brick bottom and sides, which you can readily see makes a pretty heavy floor system. I had intended to try gravel covered with sand and if it would not work pave with brick. But here comes this light, fluffy stuff, so light that a cubic foot of it dry only

weighs 15 lbs. and thoroughly wet not over 50 lbs. It is so porous that used on the floor system the rain runs right through it; the weight on an average is when packed from 35 to 40 lbs. per cubic foot. It was spread over the floor to the depth of 12 inches, taking it just as it came from the furnace. That was on for four years. It was removed last year while painting the bridge, and to my great surprise the paint under it was just as bright as when it was put on. There were only a few spots where the scale had come off and it had been attacked with rust, but nothing compared with that exposed to the open air.

At the approach to the hot metal bridge there are three tracks on a span 120 feet long which was decked over from truss to truss with $\frac{3}{8}''$ plates and channels on the outside and filled with about a foot of granulated cinder, on which the ties were laid and the rails spiked in the ordinary way and they have settled but slightly. We did not pack it, but just threw it on rough. Of course the ties crushed right down in it at first, but that was all there was to it. It does not require anything like the amount of surfacing that we have on the ground.

The advantages in maintenance, safety, convenience and quickness in dealing with wrecks and placing of frogs and switches the same as on the ground, more than compensates for the added cost. We have shifted the tracks all over the floor, put in frogs and switches, and the traffic is as heavy as anywhere in this vicinity. There is only one bridge in this country I know of that bears any comparison with the amount of travel or weight, and that is the Fort Wayne bridge across the Allegheny river. We are moving and handling loads all the time of 100 tons, not counting the weight of the car, in cars that are not allowed out of the yards, yet there has not been any appreciable settling in the cinder covered floor. I don't know clearly why, but the only way I can account for it is that it is all crystalline; like the volcanic formation, it locks together. The tie crushing into it is different from the tie on rock ballast. With ballast under the tie you have a bearing wherever it touches; but here you have every inch a perfect bearing. Yesterday I went out to see how it acted under freezing conditions. It was frozen down about four inches and below that it was just as soft and bright

as the day it was put on. This is another characteristic that makes it nice, it never gets hard. And it never gets black underneath. On the surface it is black, but it seems to gather all the impurities and keep them away from the wood, and the wood has lasted better in that material than it has on the ground.

One great feature is you can put your granulated cinder down on the floor system built as we have which is simply a trough. Build it any way you please. Put down a foot or 18 inches of granulated cinder, and the action of the train is exactly the same as on the ground, with this exception; that it rides smoother on the cinder covered floor. The matter of impact is only a small fraction of that met with on our regular open floor system of ties and guards bolted down to the stringers.

After nearly five years of watching and the hardest use I have ever seen, I unhesitatingly say that as far as I am concerned I intend to specify it right along.

The question naturally comes up, can you afford to do it; are you not going to run into expense greatly? I designed a 100-foot span just the way it is with an open floor system, and one with side girders strong enough to carry any load that comes on a bridge in case of wreck, sufficienty strong that a car can drop over on it and it would still hold at the sides, and filled with 18 inches of cinder.

The comparative weights between the two are as follows: The open system is 22,522 lbs.; the closed floor system with the ordinary road ties, 85,320 lbs., making a difference of about 63,000 lbs. additional for the granulated cinder floor in 100 feet, or about 130 lbs. per lineal foot. Now we know as railroad engineers that that amount of additional load is not going to add enough steel to the construction to throw out the possibility of using the material, at least on moderate length spans. And the riding of it is so far superior to that of the main line that there is no question for discussion.

DISCUSSION.

Mr. F. S. Rice, Mem. Eng. So. W. Pa.—What amount of this granulated slag would be sufficient on a solid trough floor bridge?

Mr. E. K. Morse—I said 18 inches. We started off with eight inches. That was not what it should be. The eight inches has settled to six inches and it is now six inches under the tie. I claim it should be a foot. Then you have just that much more cushion, that much more elasticity under your train load on the bridge, the load will ride smoother and with far better results.

There are a number of features of this material that I have not dwelt on, but it is a peculiar stuff. The re-cohesive power is very slight as compared with the sand made from the same slag. If you tack the vertical jet on to the horizontal and break it down you get said and a great portion of it is silicon and is soluble in water so that it will re-cohere and become almost like concrete if it is of the sand consistency. But I am only speaking of granulated furnace cinder. I do question that the sand should be used at all. You do not want anything that is going to set like cement, you want just the opposite. You want something light and spongy. The whole object is that it reduces the question of impact to the minimum, and is a great safe-guard in case of wrecks. It leaves the floor system so that the track construction on the bridge is the same as on the ground.

We have never discovered any fungi on the ties. There isn't any thing such as you find on decaying timber on the ground.

Mr. T. D. Lynch, Mem. Eng. So. W. Pa.—Is this material cheap enough to be used generally by railroads?

Mr. E. K. Morse—The question just now is how to get rid of it. I have mentioned Jones & Laughlin's Steel Co., simply because there is where they are using it to-day in their main bridge and hot metal bridge and where I have used it as a fill myself. But you can start from here and go to Cleveland, up the Mahoning and Shenango valleys, and every furnace is making the same stuff. It is a drug on the market and has no commercial value.

Mr. T. J. Wilkerson, Mem. Eng. So. W. Pa.—Mr. Morse has given us comparative weights, using the ordinary wood floor on stringers to compare with a solid floor from truss to truss with heavy side girders, which in my mind is not a fair comparison. I would suggest that a trough floor extending say one foot outside the ends of ties would be sufficient and would reduce the weight very materially and we would at the same time get a better floor than is used ordinarily.

Mr. E. K. Morse—The question with railroads, as I understand the economical feature, is to reduce the number of wrecks and to reduce to the mimimum the time required to get the wreck cleared up. We can not tell on a railroad where we are going to have a wreck or we would have the wrecking crew there ready. It may come on a straight piece of track, as well as on a sharp curve. You have a wreck on an open bridge or even on a half trough and it will be your fate that they will simply topple over, go in between the stringers and truss, tangle all up and also menace the structure. Put your trough clear across and fill it with granulated cinder. It is very plain that the wreck is going to act just as it has every time we have one, and I suppose we have had 50, because there are four or five switches on the granulated portion of the bridge—and not one of them has torn up enough to expose the buckle plates. It has bunched up the ties and packed the granulated cinder, but has simply made a battering ram to exhaust itself on. All we do is to run the wrecking crew up there, get the granulated cinder raked back enough to relay the ties about where they belong, throw on a few rails and go ahead.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS

The 253rd regular monthly meeting of the Engineers' Society of Western Pennsylvania was called to order in the lecture room of the Society's House, 410 Penn Avenue, Pittsburg, Pa., at 8:15 P. M., Tuesday, March 21st, 1905.

President Samuel Diescher in the chair, and 40 members and visitors present.

The minutes of the last meeting were read by the Secretary, and approved.

The report of the Board of Direction was read by the Secretary recommending the following applicants for membership:

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY
HASELL WILSON BALDWIN,	Vice-President, of the T. H. Symington Co., Baltimore, Md. h., 951 W. Fourth St., Williamsport, Pa.	Edmund Yardly. F. C. Irvine. Thos. H. Johnson.
WILLIAM LEE FEWSMITH,	Draughtsman, Heyl & Patterson, Water St., Pittsburg, Pa. h., 340 Meyran Ave., Pittsburg, Pa.	J. A. Atwood. A. R. Raymer. Edwin F. Wendt.
CHARLES STEWART FOLLER,	Mechanical Eng., Union Spring & Mfg. Co., Pittsburg, Pa. h., 55 Rogers Ave., Bellevue, Pa.	Chester B. Albree. L. G. Woods.
FRANCIS RICHARD JENNINGS,	In Engin'g Dept. Pressed Steel Car Co., McKees Rocks, Pa. h., 33 Sprague Ave., Bellevue, Pa.	Arch. Alston, Jr. Harvey Allen. F. B. Bissell.
GAYLORD THOMPSON,	General Manager, Beaver Valley Traction Co., Box 643, Beaver, Pa.	J. A. Atwood. A. R. Raymer. Edwin F. Wendt.
WALTER AUSTIN WHEELER,	Draughtsman, Riter-Conley Mfg. Co., 55-56 Water St., Pittsburg, Pa.	J. D. McLean. Z. H. Sikes. Francis S. Rice.
FRANK E. McKEE,	Electrical Engineer, Pressed Steel Car Co., McKees Rocks, Pa. h., McKees Rocks, Pa.	Paul L. Hay. Chas. A. Lindstrom. J. E. Tesseyman.

On motion the Secretary was ordered to cast the ballot of the Society electing the above applicants to membership.

Mr. George T. Barnsley—On behalf of the Reception Committee I will report that on the 25th of February, 1905, there was an excursion to the McKees Rocks Plant of the Pressed Steel Car Co., participated in by 145 of our members and their friends. The company brought their boat the "Steel Queen" to the Monongahela Wharf, Pittsburg, at 12 o'clock, where the party was received by Mr. Chas. A. Lindstrom, chief engineer of the Pressed Steel Car Co. Upon the arrival at the plant we were escorted to the dining room in the company office, where an elaborate luncheon was served, after which the afternoon was devoted to viewing the plant. Return boat trip was made, arriving at Pittsburg, at 6:15 P. M.

On March 10th, 1905, at 7:45 P. M., there was an excursion to the factory of the United States Glass Company, at 9th and Bingham Sts., S. S., Pittsburg, in response to an invitation extended by Mr. D. C. Ripley, President of the company, and was participated in by 130 of our members and their friends. The evening was spent viewing the products of the factory and the processes of manufacture. On departure, each visitor was presented with a souvenir manufactured in the works. High class pressed ware is the specialty of this factory.

March 18th, 1905, from two to four P. M., there was an excursion to the United States Weather Bureau, in and on top of the Farmers Bank Building, Pittsburg, that was participated in by 125 members and their friends. The weather being especially fine, every one present had a very enjoyable time. Mr. Ridgway and his assistants took the greatest pains to explain the working of the various instruments and apparatus to us.

Late in April there will be a "Smoker." I mention that now because I want to get the membership warmed up to it. We will send out special notices and ask the members to immediately procure tickets because the success of it depends on the co-operation of each and every member.

On motion the thanks of the Society were tendered to the Pressed Steel Car Company, United States Glass Company, and to Mr. Ridgway, thanking them for the courtesies which they

had extended to the Society, and the Secretary was ordered to transmit the same to them.

Mr. Joseph A. Shinn—On behalf of the Library Committee, I wish to call attention to the circular sent out a few days ago, soliciting suggestions on the revision of our Exchanges.

Mr. Richard Hirsh—I would like to hear from the Committee on new quarters.

Mr. George T. Barnsley—On behalf of that committee, I will say that a Joint Committee from this Society, the Railway Club of Pittsburg, the Traffic Club of Pittsburg, and the Pittsburg Foundrymens' Association have held a formal meeting to discuss the question of joint quarters for these various organizations. That committee is composed of fifteen members, and they appointed a sub-committee of five members to gather data and report to the general committee. After which, each committee will then report back to its own organization as to what can or cannot be done in the matter.

If this idea does not materialize, your committee on new quarters will have that much accomplished for the Society before the present lease expires on this building.

Mr. William C. Hawley then read a paper on "Wooden Stave Pipe," illustrated by lantern slides. After discussing the paper, a vote of thanks was extended to Mr. Hawley.

Meeting adjourned at 10:00 P. M.

F. V. McMullin,
Secretary.

The regular monthly meeting of the Board of Direction was held at the Society's House, 410 Penn Avenue, Pittsburg, Pa., Saturday, March 18th, 1905, at 8:15 P. M.

Present: Messrs. Diescher, Flanagan, Kintner, Lyons, Barnsley, Knowles, Stucki, Johnson, Maury, Anderson and Secretary.

Minutes of the preceding meeting were read and approved.

The following resignations were voted accepted: Daniel McGary and A. Kennedy Ashworth.

Treasurer's Report: Balance in bank subject to check, $4,143.01.

Secretary's Report: 923 members.

Collections since last meeting, $939.91.

On motion Secretary was authorized to place certain of the delinquent accounts in the hands of a collector, providing cost of collection does not exceed amount of bill.

The Library Committee, through its chairman, Mr. Johnson, requested the Board to appropriate sufficient money to enable the Committee to bind such volumes, as in their judgment, should be bound.

On motion, $250.00 was appropriated to enable the Committee to bind such periodicals. They were also given authority to dispose of all unbound periodicals according to their judgment.

On motion a committee consisting of Messrs. Lyons, Whited and Kintner were appointed to audit the Secretary's accounts monthly and report to the Board quarterly.

F. V. McMullin,
Secretary.

CHEMICAL SECTION.

The regular monthly meeting was held Thursday evening, March twenty-third, in the Society's House, in union with the Pittsburg Section of the American Chemical Society. Chairman Maury presided. Thirty-four members and visitors were present.

Mr. Murray C. Beebe read a paper on the "Use of Rare Earths in Electric Illuminants." After discussion and a vote of thanks to Mr. Beebe, the section adjourned.

HARRISON W. CRAVER,
Secretary, C. S.

MECHANICAL SECTION.

The regular monthly meeting was held at 410 Penn Avenue, March 7th, 1905, at 8:30 P M.

Chairman H. H. Anderson in the chair, 20 members and visitors present.

Minutes of the last meeting were read and approved.

On account of the stormy weather having reduced the attendance, it was decided to postpone the reading of Mr. J. L. Moore's paper on "Superheated Steam" to the April meeting.

Mr. Samuel Diescher then addressed the meeting on the subject of "The Flow of Water Through Pipes."

On motion the meeting adjourned at 10:00 P. M.

H. D. James,
Secretary, M. S.

STRUCTURAL SECTION.

The regular monthly meeting of the Structural Section was held at the Society's House, Tuesday evening, March 28th, 1905, at 8:30 P. M. Director T. D. Lynch in the chair, seventeen members and vistors present.

The minutes of the last meeting read and approved.

A letter from Mr. Gifford Pinchot, chief of the Forestry Bureau, Washington, D. C., asking the co-operation of the members of this Society with the Bureau in some timber tests about to be undertaken, on motion was referred to the Board of Direction of the Society, with the request that prompt action be taken on it.

Resignation of Mr. Charles Worthington as director was received and accepted, and Mr. Francis S. Rice was elected in his place.

Mr. Albert R. Raymer then read a paper on "A Marked Advance in Railroad Boiler Maintenance." The paper was discussed by Messrs. Crooker, Maury and Stucki.

On motion a vote of thanks was tendered Mr. Raymer.

On motion section adjourned at 9:30 P. M.

T. J. Wilkerson,
Secretary, S. S.

WOODEN STAVE PIPE.*

BY W. C. HAWLEY,
Member Engineers' Society of Western Pennsylvania.

A striking illustration of the conservatism of the Eastern engineers has been shown in their tardy recognition of the merits of wooden stave pipe. It is the more remarkable, since wooden pipes of various kinds were used in several cities in the East over a hundred years ago for water mains. In Philadelphia and Portsmouth, N. H., some of these wooden pipes were taken up within three or four years, and the wood was found to be in a perfect state of preservation. During the past fifty years, many mill penstocks were built of wooden staves with flat bands. In 1874, Mr. J. T. Fanning built a 6-foot penstock at Manchester, N. H., which is still in service. At Wicopee, Dutchess county, N. Y., on Fishkill creek, there was, in 1893, a 30-inch stave pipe which had been in use for power purposes for 45 years. It was reported at that time in good condition and fit for many more years of service.

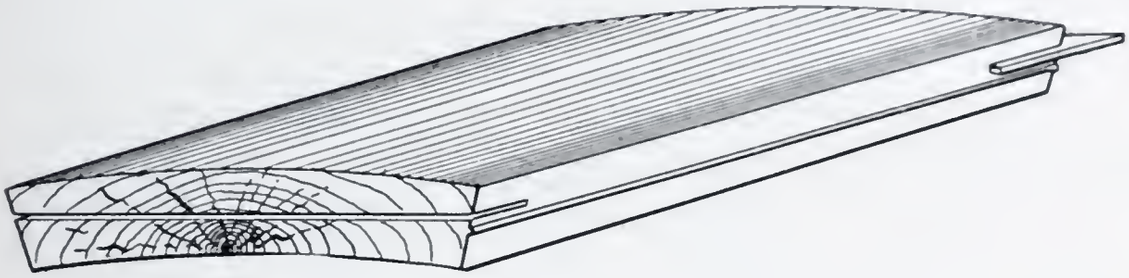
It remained, however, for the engineers of the far West, when faced by the high price of cast iron, wrought iron and steel, to develop a form of construction for wooden pipe, which has, within the past 25 or 30 years, been very largely used in that section of the country, and which is just beginning to find its way into the East.

It should be clearly understood that wooden stave pipe is not going to displace cast iron or steel pipe entirely. Under certain conditions, it undoubtedly has its advantages, as will be pointed out; under other conditions, cast iron or steel will be found preferable.

The construction of the pipe is shown by Figure 1. It is made with staves with concentric inner and outer surfaces and radial edges. The ends of the stave are scarfed about $\frac{3}{4}$-inch

*Read at meeting of the Society, March 21, 1905.

deep, and a steel plate of No. 12 or No. 14 gage, and slightly longer than the width of the stave, is inserted. The staves are held in place by round or oval steel bands, the spacing of the



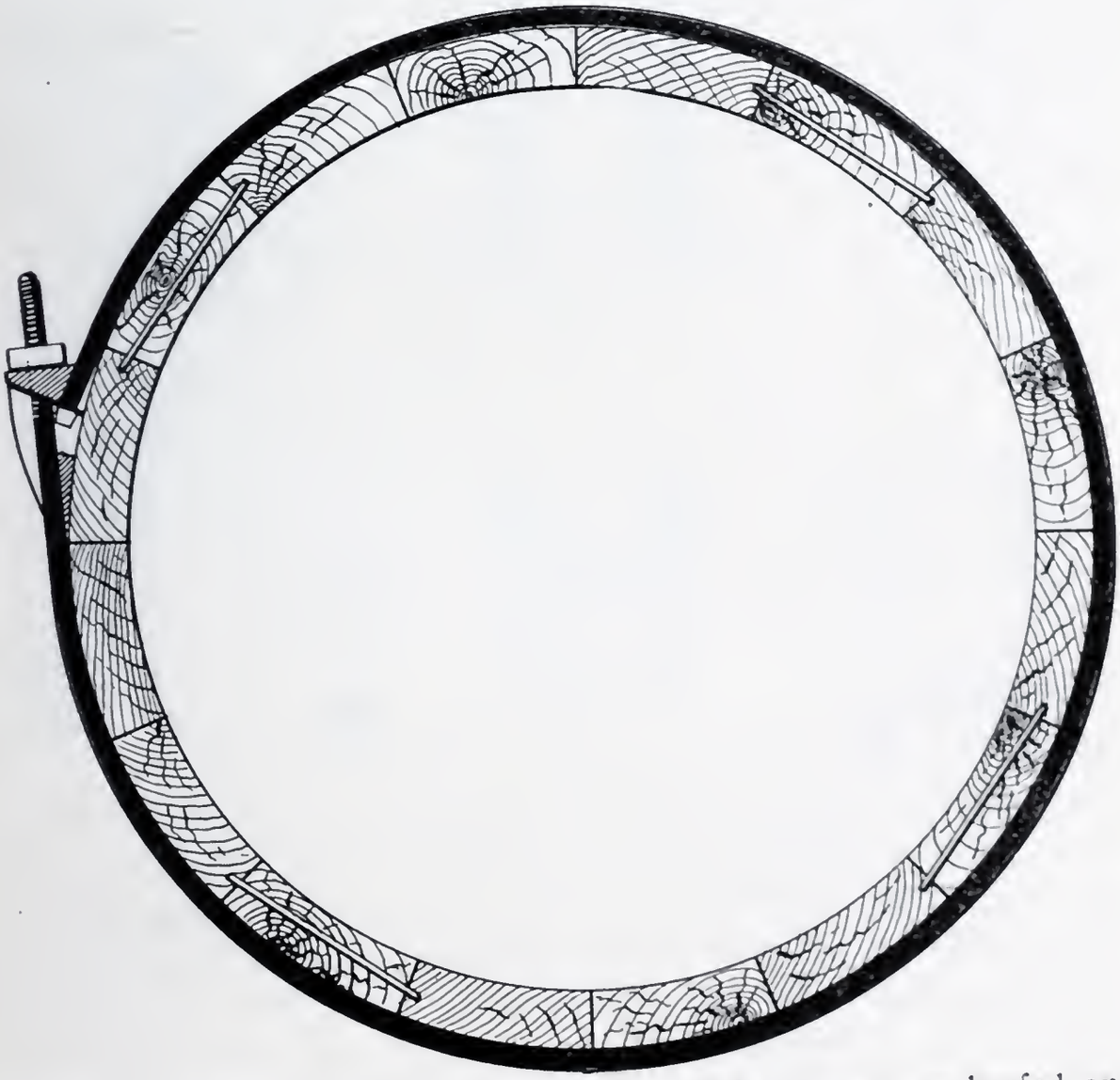


Fig. 1. Showing section of pipe and how the staves are kerfed and plate inserted to make butt joint.

bands depending upon the pressure. Sometimes a small bead is left on the edge of the stave, which, being forced against the adjoining stave edge, will fill any slight depression or irregularity of the surface, thereby reducing the chance of leakage. The bands are secured by a coupling shoe, the more common form of

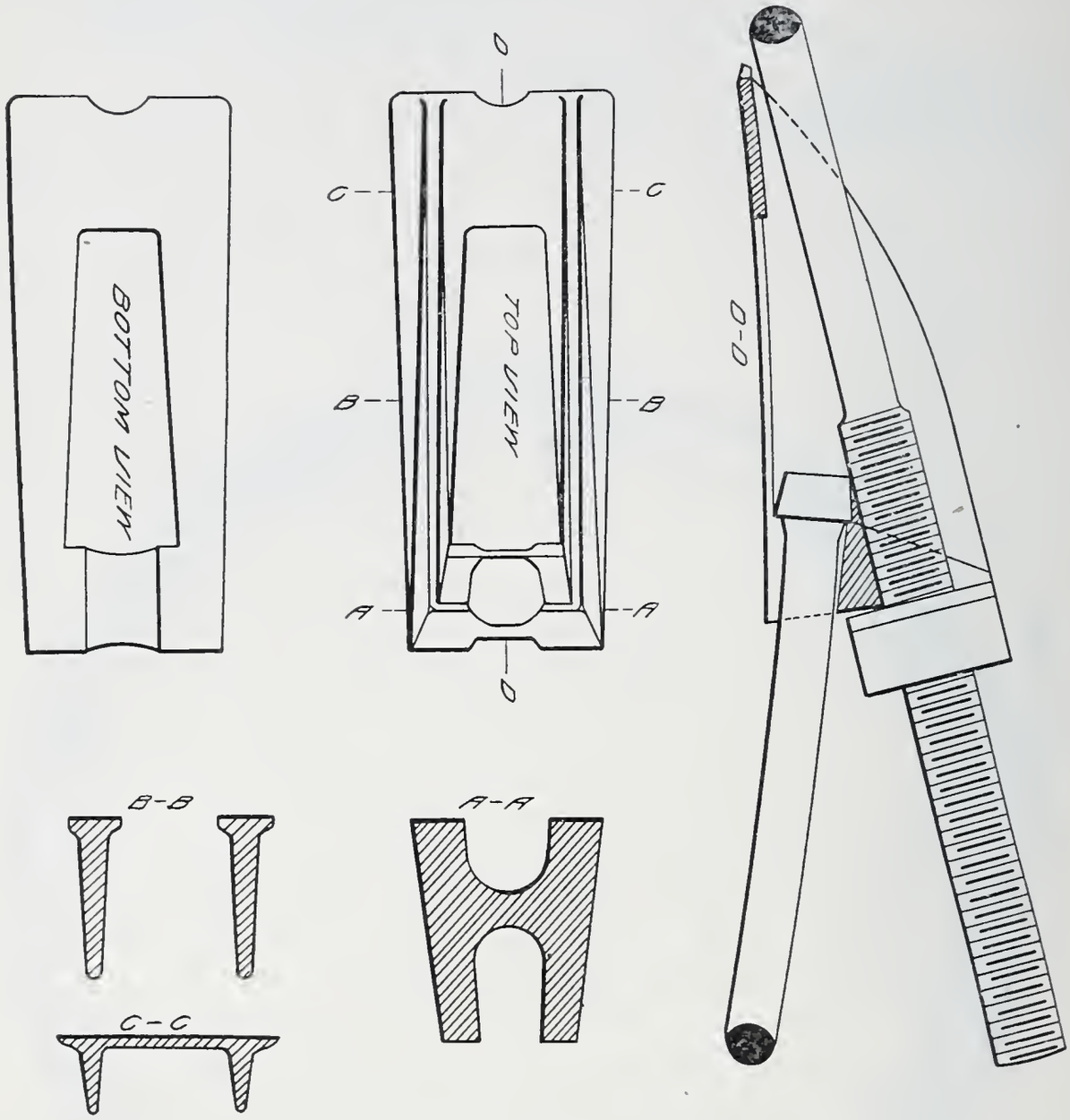


Fig. 2. Showing saddle and method of securing band.

which is shown by Figure 2. The band has (usually) a T-head which locks into the under slot of the shoe, and the other end is threaded and provided with a washer and nut. Shoes are usually made of cast or malleable iron, and rods of soft or medium steel. The rod is swelled just below the head to prevent danger of breaking at that point; and the threaded end is either upset so that the

diameter at the base of the thread, is about as large, or slightly larger than that of the rod, or else the thread is pressed or rolled. Specifications usually call for tensile test of rods, and that they shall not break close to head nor in the threads.

In constructing the pipe, staves are placed over a form, care being taken to break joints at least 18 inches. The bands are spaced uniformly, and then "cinched" by turning up the nut, and at the same time rapping the band smartly with a mallet so as to secure the necessary indentation of the staves. Curves are made by forcing the pipe up or down or sideways after the bands are placed, but before they are "cinched," and holding it in the desired position while "cinching."

The lasting qualities of the pipe depend upon the complete saturation of the staves, and the thorough protection of the bands, saddles, etc., by an asphalt or similar coating. The staves must be thick enough to prevent percolation of the water through them, and to prevent bending between the bands. Experience has shown that with a pipe under pressure, any reasonable thickness of stave will be saturated, so that practically, percolation and bending only have to be considered. There is, however, the further practical consideration that staves are usually run from 2"x6", 2"x8" and 3"x8" stock lumber, which affects the thickness of stave from some sizes of pipe. See table No. 1.

The protection of the bands, saddles, etc., is usually accomplished by dipping them in a bath of melted asphalt or "Mineral Rubber." After "cinching," the bands, etc., are carefully painted before backfilling, either with the hot coating material, or some suitable paint.

Within the limits of this paper, it will not be possible to go very deeply into the theory of the design of wooden stave pipe. Those who care to do so, will find an elaborate paper and discussion on the subject by Mr. Arthur L. Adams, in Vol. XLI. of Transactions of the American Society Civil Engineers.

In discussing that paper, Mr. D. C. Henny, engineer of the Excelsior Wooden Stave Pipe Co., of San Francisco, gives the following method of computing the stresses and designing Wooden Stave Pipe.

Let R=internal radius of the pipe, in inches.
" r=the radius of the band section, in inches.
" t=the thickness of the stave, in inches.
" f=the spacing of the bands between centers, in inches.
" S=the tensile stress in the band, in lbs.
" s=the safe tensile strength of the band in lbs.
" P=the water pressure, in pounds, per square inch.
" E=the permanent sustaining power of the staves, in lbs., per lineal inch of band.
" E=the permanent swelling force of the wood, in lbs., per square inch.
" e=the safe bearing power of the wood, in pounds, per lineal inch of band, say 140 to 262 lbs.
" y=the average compressive lateral stress in the staves, per square inch of compressed section, when the pipe is under pressure.

It is evident then, that—

$$S=P\ f\ R+f\ t\ y. \qquad \text{(a)}$$

The maximum value of this, is—

$$S\ max=P\ f\ R+f\ t\ E' \leqq (R+t)\ E \qquad \text{(b)}$$

Of this Mr. Henny says:—

"This maximum strain can be attained only by recinching after the pipe has become filled and is under pressure, which is rarely, if ever, done in practice. In case the pipe is cinched up to the limit, the strain in the band may be f t E″ before filling. When pressure comes on, the staves will be forced outward owing to the compression of the wood immediately under the bands, and to deflection between the bands, to which the author has duly called attention. While this motion is small, it lessens materially the lateral compression of the staves, and relieves, to that extent, the portion of the band strain due to stave compression. The extent of relief being unknown, it would not be practicable to take cognizance of it in the determination of maximum strains, but so far as formula (a) is concerned, it may be stated that as P becomes larger for any given pipe, y becomes smaller, until finally leakage results.

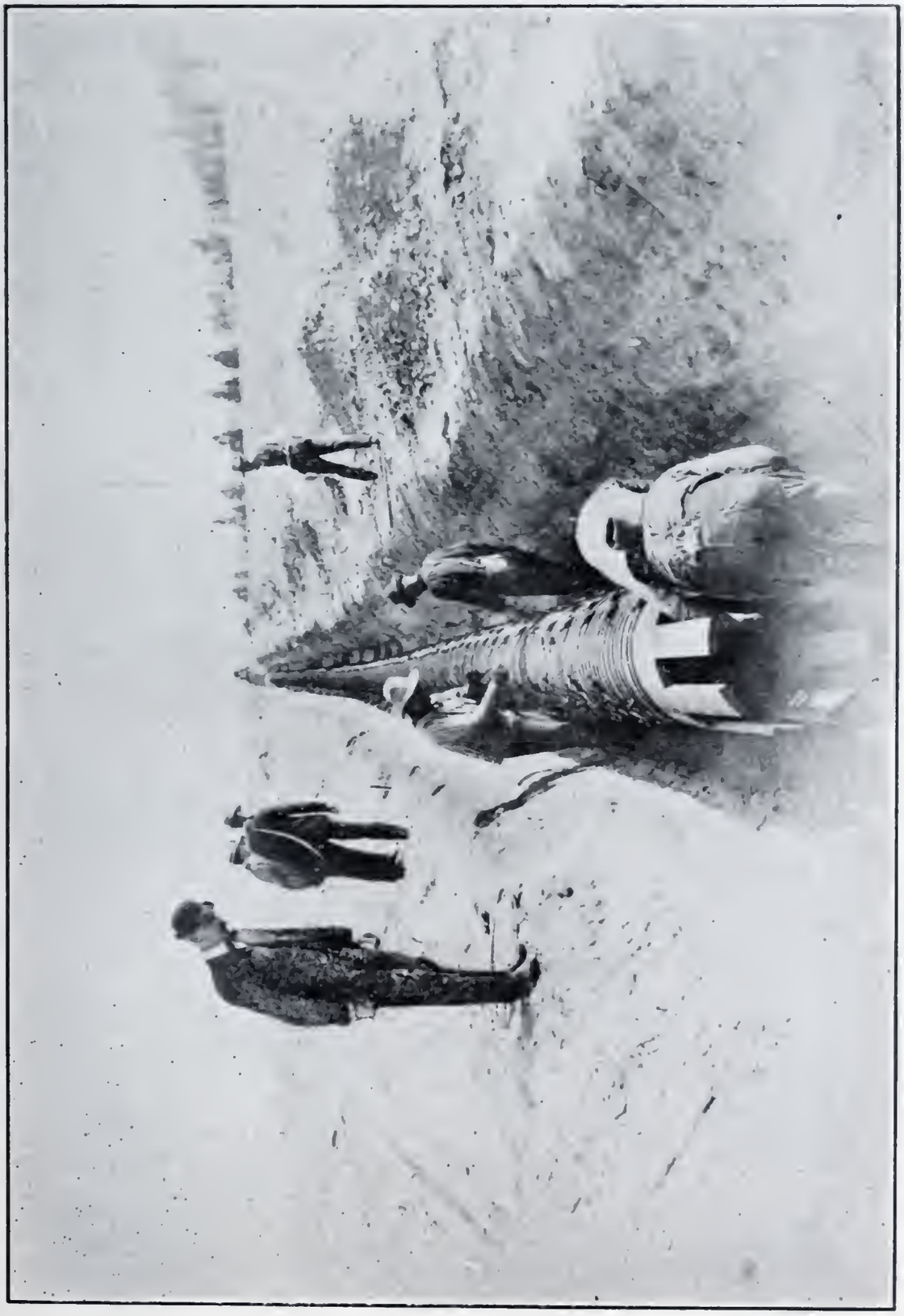


FIG. 3. 26-inch pipe at Butte, Mont. "Cinching."

"The maximum band strain, as expressed by formula (b), is greater than that required for tight pipe. When, on a pipe under pressure, the strain in a band is released by turning the nut, the compressive strain on the staves will be decreased, until finally, leakage in the seam joints results, commencing half way between the bands where the compressive strain is least. Calling the stave compression half way between the bands y_1, and that at the bands y_2, the average stave compression y will be approximately $\frac{y_1+y_2}{2}$ and the condition of tightness will be expressed by $y_1 > P$.

Where the spacing of the bands is not wide, and where the staves are not unusually thin (conditions referred to hereafter) y_2 will generally be but little greater than y_1, consequently, $y_1 + y_2$ will be little greater than $2y_1$, and, with the exceptions noted, it is believed that tightness is generally insured by the condition $y_1 + y_2 = 3P$ or $y = \frac{3}{2} P$. Substituting in formula (a), their results for the least band strain in tight pipe:

$S = P f R + ft \frac{3}{2} P$, which should be equal to the safe tensile strain in the band; hence,—

$$s = P f (R + \tfrac{3}{2} t),—$$

So far as indentation under the band is concerned, the safe bearing power under the band should not be exceeded by the safe band strain; therefore,

$$s = Pf (R + \tfrac{3}{2} t) \leqq (R + t) e \qquad \text{(c)}$$

from which the spacing

$$f = \frac{s}{P (R + \frac{3}{2} t)} \leqq \frac{(R + t) e}{P (R + \frac{3}{2} t)} \qquad \text{(d)}$$

The value of e, as given by Mr. Henny, varies from 140 lbs. for a $\frac{3}{8}$-inch band to 262 lbs. for a $\frac{7}{8}$-inch band, these values being based on a pressure ranging from 747 lbs. per sq. in. of contact of band and stave for a $\frac{3}{8}$-inch. band, to 600 lbs. per sq. in. for a $\frac{7}{8}$-in. band.

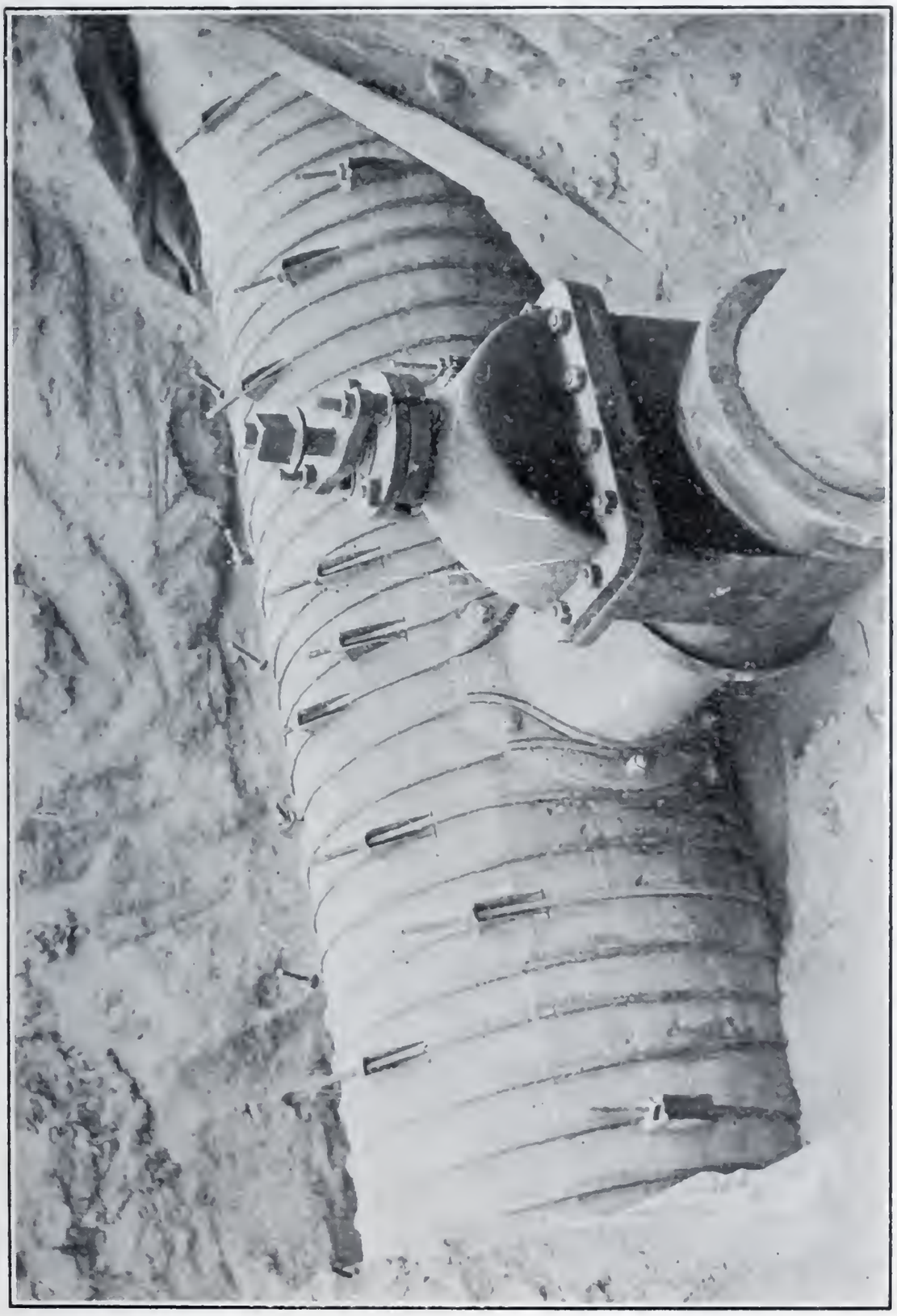


FIG. 4. 30-inch pipe, showing how a branch is put on when pressure is not high.

Mr. Adams gives the following table:—

Table No. 1.

ECONOMIC PROPORTIONS FOR PIPE DESIGN.

Nominal diameter. Inches.	Stock sizes for staves.	Thickness of staves.	Economic sizes of bands.
			O
10	1 1/2" x 4"	1 1/16"	5/16 x 7/16"
12	1 1/2" x4 "	1 1/8"	5/16 x 7/16"
14	1 1/2" x 4"	1 3/16"	5/16 x 7/16"
16	2" x 6"	1 7/32"	5/16 x 7/16"
18	2" x 6"	1 3/8"	5/16 x 7/16"
20	2" x 6"	1 3/8"	5/16 x 7/16"
			O
22	2" x 6"	1 3/8"	3/8"
24	2" x 6"	1 3/8"	3/8"
27	2" x 6"	1 7/16"	3/8"
30	2" x 6"	1 1/2"	1/2"
36	2" x 6"	1 9/16"	1/2"
42	2" x 6"	1 5/8"	1/2"
48	2" x 6"	1 11/16"	1/2"
54	2 1/2 x 8"	2 1/8"	5/8"
60	3" x 8"	2 1/2"	5/8"
66	3" x 8"	2 9/16"	3/4"
72	3" x 8"	2 5/8"	3/4"

In practice it is found that bands exceeding $\frac{3}{4}$ or $\frac{7}{8}$-inch, are too difficult to handle and "cinch" well. In cases of low pressure, the maximum band spacing is usually 12 inches.

Wooden stave pipe is not suitable for high pressures. For instance assume a 30-inch pipe under 100 lbs. pressure.

In equation (d) we have,—

$R = 15$

$r = .25$

$P = 100$

$t = 1.5$

$s = 12000 \times .196 = 2352.$

$$\therefore f = \frac{s}{P\,(R + \frac{3}{2}\,t)} \leq \frac{(R + t)\,e}{P\,(R + \frac{3}{2}\,t)} = 1.36 \text{ inches.}$$

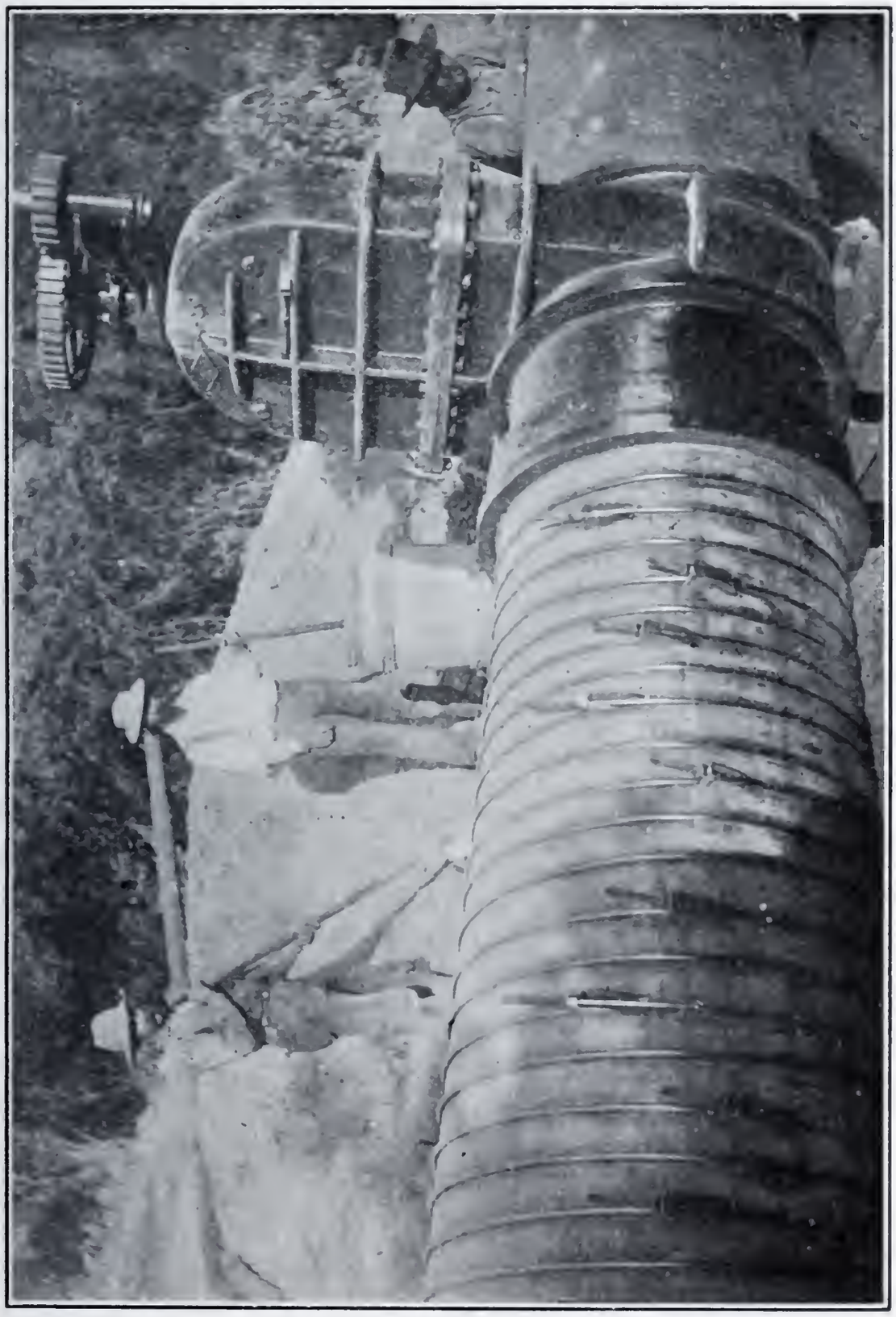


FIG. 5. 36-inch pipe reduced to 30-inch, to allow use of 30-inch gate valve.

It becomes evident that this spacing would barely allow room enough for the saddles. Besides, the quantity of steel, per unit of length, is almost what would be required in a riveted steel pipe, and unless other considerations enter, a riveted steel pipe would, probably, be cheaper. Thus it will be found that wooden stave pipe is not economical when the pressure exceeds 90 to 100 pounds.

In judging the merits of wooden stave pipe. we compare it with cast iron and riveted steel pipes,—

(1.) LIFE. So long as the staves are kept saturated, they will last indefinitely. The life of the bands depends upon the perfection of the coating, and it is manifestly easier to obtain, by thorough inspection and good workmanship, a perfectly coated band, than to secure the handling, laying, riveting and subsequent repair to the coating of a riveted steel pipe, no matter how excellent the original coating of the pipe may have been. The same remarks apply to cast iron pipe, except that cast iron does not rust so rapidly as steel. In places where subject to salt, acid, alkali or electric current, the wooden stave pipe is preferable to either steel or cast iron.

(2.) EASE OF REPAIR. The only repairs that can be needed to a wooden stave pipe, are to replace damaged or defective bands or staves. In case of a band, the repairs are obviously simple and easy. If a stave or staves are to be replaced, the bands are loosened and slipped back on the pipe, the stave or staves pried out, new ones cut, scarfed and buckled in to the place of those removed and the bands replaced. These operations are hardly as difficult as putting a boiler patch on a riveted steel pipe, or replacing a broken cast iron pipe with a new one.

(3.) RELIABILITY. Wooden stave pipe which has been properly designed, cannot burst. Should an excessive pressure be put on the pipe, the staves would be forced back against the bands and thus relieve the pressure between the edges of the staves, which results in leakage, and a consequent reduction of the pressure in the pipe. Should this happen, the elasticity of the staves would, to a large extent, restore the pipe to its original condition.

Compared with cast iron pipe, wooden stave pipe has the advantage of being without joints. The lead joints in a cast iron

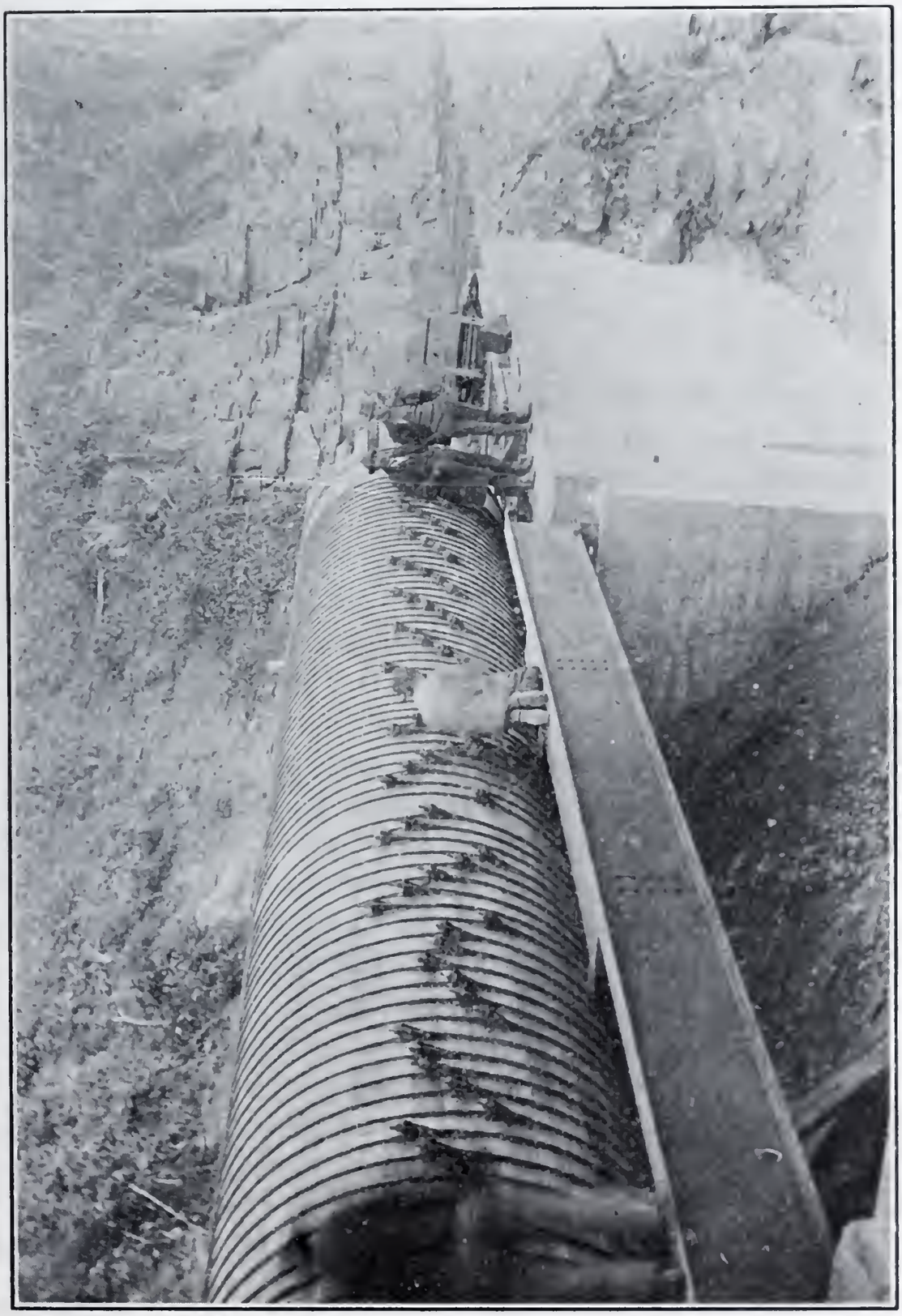


FIG. 6. 84-inch wooden stave pipe.

pipe, are points of weakness especially if the pipe is subject to vibrations, water hammer or settlement. The continuous structure of the stave pipe avoids this, and gives a high degree of elasticity. This, and its light weight, gives stave pipe an advantage over cast iron or steel for lines through marshes, quicksand, and other places where the iron or steel would settle unless supported on piling, cribbing or platform.

(4.) Ease with Which Material May be Transported and Pipe Constructed. The transportation of staves and bands in mountainous countries, over bad roads, or in swamps, is so much easier and cheaper than handling cast iron or steel pipe, that its advantage in such cases is manifest. This is especially true of pipe of large sizes. Stave pipes have been built in locations where it would have been almost, if not quite a physical impossibility to have laid anything else, and even if it had been physically possible, the cost would have been prohibitive.

The remarkable elasticity and light weight of stave pipe, makes its construction in swamps, or other ground where large quantities of water are encountered in the trench, much less expensive than that of metal mains. It can be built on timbers over the trench and lifted by derricks or jacks, the timbers removed and the pipe then lowered into the trench. It will float on the water in the trench, which can then be pumped out thereby lowering the pipe to its place in the trench. The pipe can then be filled with water and the trench backfilled. As soon as the staves become saturated, there will be no danger of floating.

(5.) Capacity. The capacity of a wooden stave pipe is as great, or slightly greater than that of cast iron pipe, when new. There is no subsequent deterioration or roughening of the inner surface of wooden pipe to reduce its capacity, while tuberculation of the cast iron pipe has, in some cases, reduced the capacity of large pipes by as much as 30 per cent. Compared with riveted steel pipe, the experiments of Marx, Wing and Hoskins (see Vol. XLIV. Transactions Am. Soc. C. E.) show in a 6-ft. riveted steel pipe, when new, the value of C in the Chezy formula is about 110, while two years later it was about 105. In a 6-foot, wooden stave pipe, the value of C was about 122 when new, and also when tested two years later.

(6.) Cost. The possible economy of wooden stave pipe, compared with cast iron or steel, must be determined for each case. With other conditions equal, and pressure ranging from 60 to 75 pounds, it is probable that there would be little, if any, saving in wooden stave pipe in sizes less than 30 inches in diameter. With low pressures, there might be some saving down to 24-in. For the same pressure, the saving increases as the diameter increases, and for the same diameter, the saving increases as the pressure decreases. The writer knows of a large power development scheme which became a commercial possibility by the saving made by changing part of a line of 7-ft. riveted steel pipe to wooden stave pipe.

The following extracts from specifications of wooden stave pipe may be of interest:—

"Staves. 14. The staves shall be made either from California Redwood, from Oregon or Washington Fir, or from Texas long leaf Yellow Pine, the bidders are asked to submit proposals for pipes built of either wood. The staves shall be made from perfectly clear, first quality lumber, as well seasoned as the market affords, perfectly sound and free from sap, spongy grain, knots, shakes, dry rot, pitch seams, cracks or other defects that may impair its strength and durability. The stave lumber shall be placed on sticks immediately after being sawed, so that the air may freely circulate between and around it, and shall remain on said sticks, in the case of Redwood, not less than two months, and in the case of Fir, not less than three months before being manufactured into staves. Before the manufacture of staves is commenced, the templates must be submitted to the Superintendent for his approval.

"The staves shall be dressed from two (2) inch by six (6) inch lumber, and the finished thickness shall not be less than one and one-half ($1\frac{1}{2}$) inches, the flat sides being dressed to conform to the inside and outside circumference of the pipe, the edges being dressed to true radial planes.

On one edge of the finished stave, there shall be a small bead, as shown. All staves shall be finished in lengths from twelve (12) to twenty-five (25) feet, but not more than ten (10) per cent. shall be less than fifteen (15) feet in length.

The ends of the staves shall be sawed accurately square with sides, and shall be fitted with a saw-kerf for the insertion of a wrought iron or steel plate, of No. 12 B. W. G. as shown on the plans. The saw-kerf shall be of such dimensions as to make the tongue fit tight in all directions and cut across the end of the staves in exactly the same position for all the staves.

"In delivering the staves, they shall be carefully assorted as to grain, and the bastard grained staves shall be used in the heaviest pressure portions of the pipe line. After the staves are delivered on the work, they must be properly taken care of, in order to prevent them from warping or distorting, as only staves found perfect in every particular will be accepted and permitted to be used in the pipe.

"Bands. 15. The bands shall be of homogeneous 'mild' steel, having a tensile strength of from 58,000 to 65,000 pounds per square inch of section; an elastic limit of at least sixty (60) per cent. of the tensile strength; an elongation in eight (8) inches, not less than twenty-five (25) per cent.; a reduction of area at point of rupture, of at least fifty (50) per cent., and shall be capable, when cold, of being bent back flat upon itself without showing signs of fracture. The steel must not contain more than five one-hundredths (0.05) per cent. of sulphur; five one hundredths (0.05) per cent. of phosphorus; five one-hundredths (0.05) of silica; and five-tenths (0.5) per cent. of manganese.

"The section of the band shall be a circle with a diameter of one-half ($\frac{1}{2}$) inch, and the band shall have a T head at one end, and at least five (5) inches of rolled thread at the other. The threads shall be stronger than the body of the bolt, and this shall be proved from records of tests to be made by a reputable firm of inspectors, copies of which shall be furnished the Superintendent.

"All bands shall be slightly swelled beneath the bolt heads, and provided with necessary standard threads, nuts, and washers; the threads shall be cut to such length as may be required to properly build the pipe in accordance with the plans and specifications, and subject to the approval of the engineer. There shall be no sharp edges or points on the head or end of the finished rod. The rods or bolts shall be of such length that when in place, they

shall extend through the nuts for a distance of not less than two inches nor more than four inches.

"COATING. 18. The bands, nuts, washers and saddles shall be thoroughly cleaned of all scale, rust, oil, dirt, etc., and the bands bent around a bending table to fit the exterior circumference of the pipe. They shall then be coated by being dipped in hot mineral rubber or other material equally as good, to be approved by the engineer, after having been heated to 400 degrees Fahrenheit. This coating must adhere firmly to the metal, and must not flow at a temperature of 150 degrees Fahrenheit, nor be brittle at 32 degrees Fahrenheit. It must cover the metal perfectly to a thickness of at least one-fiftieth (1-50) of an inch."

Among the places where wooden stave pipe has been used in the East, are the following:—

The Cambria Steel Co., of Johnstown, Pa., has recently laid several miles of diameter between 40 and 50 inches. At Atlantic City, New Jersey, 9807 feet of open canal was replaced by a 42-inch wooden stave pipe, at a cost of $28,425.65, or about $2.90 per lineal foot. Lynchburg, Va., has recently let a contract for 106,000 feet of 30-in. pipe for its water supply.

DISCUSSION.

MR. W. G. WILKINS, Mem. Eng. So. W. Pa.—I have here a piece of wooden pipe that was used in Steubenville, Ohio. It was taken up in 1895, and you can see that although it has been out of the ground about ten years, there is no evidence of decay except on the outside. It has been the result of my observation of water soaked timber when taken out of the ground that on drying out it begins to show signs of decay. Mr. Ross who had charge of the construction of the new water works at Steubenville and who took up the piece of pipe, says that when taken out it was perfectly sound.

The first public water works in Steubenville was built in 1835 and some of the old inhabitants said that this wooden pipe was laid about 1800 to take the water from a spring on the hillside to supply Fort Steuben.

MR. F. G. ROSS, Mem. Eng. So. W. Pa.—This piece was buried about four feet deep in very wet ground. Where the pipe was in dry ground it had entirely rotted away.

Mr. L. E. Chapin, Non-Member—You say that if a pipe be thoroughly saturated its life is prolonged. You mean by that interior saturation obtained if the pipe is filled with water.

Mr. W. C. Hawley—As long as the pipe is running full or under pressure so that it is saturated, I think the life is indefinite. At Rochester quite a number of years ago, they had a wooden stave pipe which was never put into service, at any rate they turned water in and it leaked so badly that it was abandoned. This was before they knew much about wooden stave pipe in the east. When they came to lay the riveted line which was afterwards put in, they uncovered a lot of this pipe. Part of it lay in ground that was wet, and in that ground the pipe was perfectly preserved. Other parts, in ground that was dry, was rotted out completely—though the pipe had had no water in it in either case.

Mr. H. D. James, Mem. Eng. So. W. Pa.—Would exposure to the direct rays of the sun have a deteriorating effect upon the wood? Wouldn't the sun dry it off faster than the water would percolate through to the outer layer, and cause rotting?

Mr. W. C. Hawley—My own personal idea would be to use some protection for a pipe that is exposed. Near Butte, Montana, the pipe is uncovered and the staves appeared to be perfectly dry. I stuck the point of a penknife into the staves and the water squeezed out on both sides of the blade, showing that the staves were entirely saturated to the outer skin.

Mr. Ralph Crooker, Jr., Mem. Eng. So. W. Pa.—I saw a wooden pipe taken up that was banded by flat iron bands drawn around it and fastened here and there with nails. When these pipes were removed they practically fell apart. It was really only the earth holding them in place, and I was wondering how long these bands, $\frac{3}{8}$ or $\frac{5}{8}$ inch, would last in the ground?

Mr. W. C. Hawley—If they are properly protected they should last indefinitely. We made a short time test of them at Atlantic City, putting a section of this pipe into the soft mud. In the meadow mud there a steel or wrought iron bolt was so eaten away in a few months that you could strip the nut right off. You could see the fibre in the metal as though it had been

pickled in acid. But with the bands coated with mineral rubber or some such material, the metal was perfectly protected. I think it is only a question of the proper protection. Mineral rubber as it is used will ordinarily give a thickness of 1/50 to 1/20 of an inch. It is an asphalt compound and if it is put on properly there is no reason why the band should not last indefinitely. The experiments made with mineral rubber show that it is not affected by salt water or fresh water.

I saw at Butte a line of pipe that had been laid nine years. A storm had uncovered it for several feet and the bands were in perfect condition. At Seattle they have used a wooden stave pipe for a sewer, two-thirds of which is exposed at low tide, and there the staves had rotted a little bit at the ends. That pipe had been in service seven years. But the bands that had been dipped in asphalt were in a good state of preservation.

Mr. Ralph Crooker, Jr.—Had they painted the outside of the wood?

Mr. W. C. Hawley—No, sir.

Mr. Samuel Diescher, Mem. Eng. So. W. Pa.—If staves are thoroughly seasoned, does it not occur sometimes that owing to subsequent swelling of the wood, the bands burst?

Mr. W. C. Hawley—A few years ago the idea was to season the wood and let it swell as tight as it would when the pipe was put together. When the pressure is put on the staves are forced back against the bands and the pressure between the edges is thus somewhat reduced. Within the last two or three years engineers have come to the conclusion that it is better not to season the wood so much, but to put it in rather green. These staves are made of the very best quality of lumber, absolutely free from knots, cracks and shakes or any fault that can be found in lumber. If it were not then the band would not bear uniformly over the stave and the result would probably be leakage.

As to sizes of pipe, at Redlands, Cal., there is a wooden stave pipe nine feet in diameter. That is the largest one I know of. One at Utica, N. Y., is a seven foot pipe. And they have been laid from that down as small as a ten inch pipe.

MR. ARNOLD STUCKI, Mem. Eng. So. W. Pa.—Did the pipe that was in the ground about a hundred years have an iron band or a wooden band?

MR. W. C. HAWLEY—The pipe in Philadelphia was a log pipe about 8 or 10 inches in diameter, and the joints were made with a cast iron thimble driven in the ends.

MR. SAMUEL DIESCHER—Suppose the pipe is to be reduced in order to connect it with a valve with openings smaller than the diameter of the pipe, must the necessary tapering of the staves be made at a mill or can it be done by hand, in the field?

MR. W. C. HAWLEY—That can be done very readily by hand. It requires considerable skill, but any good carpenter ought to be able to do it.

MR. RALPH CROOKER, JR.—In kerfing the ends of the staves. a little piece of steel plate is set in that extends beyond the width of the stave itself. When they come, as in Figure 3, to push the staves up together, do they sink that kerf the whole distance?

MR. W. C. HAWLEY—The little steel plate is put into the end of the stave when the stave is put into place and before the adjoining staves are cinched up against it so that it cuts only into the adjoining stave about $\frac{1}{8}$ inch, and the next stave is driven home against it.

MR. RALPH CROOKER, JR.—I can see how in replacing a stave they might get into the first one of these kerfs, but how do they get into the second one?

MR. W. C. HAWLEY—They would take out one stave, and replace it by two staves that are just the length of the one taken out. Their ends are kerfed, a plate inserted between the two and then they are sprung into the place of the stave which has been removed.

MR. H. D. JAMES—Does the longitudinal pressure in the pipe on curves and in change of section, have any tendency to part the pipe or is the bonding between the staves strong enough to hold the pipe without anchoring?

MR. W. C. HAWLEY—I don't think the strains that are set up in bending need be considered at all. I never have known

of a case of a pipe being injured in that way, as the cinching is done after the staves have been bent to the desired position.

MR. MORRIS KNOWLES, Mem. Eng. So. W. Pa.—Can it be laid around ordinary street corners?

MR. W. C. HAWLEY—No, hardly as sharp as that. One of these pictures shows a steel pipe that was used to make a sharp turn. I think that pipe, 42 inches diameter, had a radius of 250 feet.

MR. L. E. CHAPIN—Is there any relation between the diameter of the pipe and the minimum radius of curvature? In other words, with a 42 inch pipe, you say 250 feet is the minimum radius. Does that same relation obtain with a 24 or 20 inch pipe?

MR. W. C. HAWLEY—I presume you could lay a 20 inch pipe around a smaller radius than a larger pipe.

MR. L. E. CHAPIN—Is Texas pine any better or not as good as Georgia pine?

MR. W. C. HAWLEY—The difficulty with Georgia pine is that so much of it has been tapped for turpentine. If it was not tapped it would be as good as Texas pine.

MR. SAMUEL DIESCHER—According to a report on Timber Physics of long leaf pine, issued by the Forestry Division of the U. S. Agricultural Department, there is no difference in the quality between boxed and unboxed timber. And as to appearance, even experts cannot distinguish one from the other.

MR. W. C. HAWLEY—I think that is correct. But my understanding of the matter is, that the difficulty in using that wood for pipe staves is that you will get one stave, perhaps, that has been boxed and one that hasn't. The different parts of the same tree will be different so that you get different qualities of wood, and the bands will not cinch into the wood uniformly as they do with wood like redwood or fir.

MR. G. H. DANFORTH, Mem. Eng. So. W. Pa.—Would the increased cost of getting oval material and upsetting the ends overbalance the advantage of using bands made of that section.

MR. W. C. HAWLEY—I can only answer by saying that Mr. Adams in his article states that up to a short time before his article was written that was true. But at that time it was possi-

ble to get a rolled oval section at a cost which would make a saving as compared with round bands.

Mr. L. E. Chapin—Suppose we wish to use some of this pipe. Must we get Mr. Allen to make it?

Mr. W. C. Hawley—No, sir; the patents have expired. However, there are tricks in all trades, and from what I saw of pipe laying out west, I believe it would pay to get a man like Mr. Allen or Mr. Henney, who has had a little experience and knows these tricks.

Mr. Morris Knowles—One of the most interesting points about this pipe to me, is its carrying capacity and the continuance of that carrying capacity through several years of life. The deterioration in metal pipe is due to more than one cause. That which we realize most generally, incrustation or the forming of tubercles when rust attacks the pipe, either because it is uncoated or continues after the same has been applied underneath the coating. Thus little projections are formed into the interior of the pipe, lessening the diameter and also causing roughness, which produce undulating currents and destroy the straightness of the current, and cause a loss of head.

In leading the joints of cast iron pipe, an unevenness is frequently produced and in steel pipe, due to the rivet heads, because rarely do we have counter-sunk rivets, and due, also, to the telescopic method of making steel pipes, projections into the pipe area are caused. These things will be entirely avoided by the use of wooden stave pipe.

There is one other method of lessening capacity and I would be glad to have Mr. Hawley tell us whether it occurs in wooden pipes, due to microscopic organisms forming a gelatinous mass, or growth, inside the pipe, causing a reduction of diameter. We know of a number of aqueducts where that has very seriously reduced their capacity, and it has been necessary to go through them in boats and clean them out by scrubbing and scraping off this gelatinous growth to bring back the capacity. That could be done in wooden pipes of course if they were large enough. I would like to know if in any wooden pipes the capacity has been impaired from this cause.

Mr. W. C. Hawley—I believe that Mr. Henney, who has had a great deal of experience, has stated that so far as his knowledge goes he has never known of a growth of this kind on the inside of a stave pipe. Mr. Allen, of Denver, who has laid a good many miles, stated to me that he knew of nothing of the kind. The pipe has been largely used for water works purposes in the west, as well as for power and mining. In Seattle there are some 20 or 30 miles of pipe from 42 up to 54 inches. Denver, Colo., Astoria, Ore., Portland, Ore., San Francisco and a number of the coast cities receive their supplies from wooden stave pipes. The only experiment I know of which will determine this question is that made by Marx, Wing and Hoskins on the Pioneer Power line at Ogden, Utah, which I believe was a six foot line, and the value of C in the Chezy formula was found to be the same after two years' use.

NOTES ON THE USE OF RARE EARTHS IN ELECTRIC ILLUMINANTS.*

BY MURRAY C. BEEBE,
Member Engineers' Society of Western Pennsylvania.

As scientists and engineers have come to a realization of the inefficiency of existing methods of illumination, the problem of improving upon these inefficient methods has received considerable attention. While the element carbon has, heretofore, been almost exclusively used commercially in both arc and incandescent lamps, the rare earth oxides, so called, have recently been found to possess desirable properties for use as illuminants.

We are already familiar with the work of Auer von Welsbach in producing gas mantles of thoria and ceria. To use the rare earths in electric illuminants was a logical step. However, the problem possessed difficulties not encountered in the production of a serviceable gas mantle. We should remember that an illuminant, to be an improvement over the Edison or carbon filament lamp in the matter of efficiency, must be capable of withstanding a higher temperature than the carbon filament for a length of time sufficient to make it commercially attractive. One might at first suppose that it would be difficult to improve upon the carbon filament in the matter of efficiency, or the ability of the filament to operate commercially at a very high temperature, since carbon is practically infusible and the rare earths are fusible. Carbon, however, slowly vaporizes at the temperature at which it operates in the incandescent lamp, and finally, after 400 to 600 hours, has depreciated in light giving power to such an extent that it is best to replace it. It is the vaporizing properties rather than the melting points of the materials, with which we are concerned in this problem. It has long been known that substances which are commonly regarded as insulators; such as glass and

*Read at meeting of the Chemical Section, March 23, 1905.

porcelain, become quite good conductors of electricity at higher temperatures.

Prof. Buff, in 1854, read a paper "On the Conductivity of Heated Glass for Electricity," and "Faraday's Researches," gives a number of examples of such conductors. Jablochkoff, as you know, attempted to use refractory materials, such as lime, to separate and insulate the carbon electrodes of his Jablochkoff candle. He soon found that these supposed insulators in reality became conductors and emitted light by virtue of the current passing through them from one electrode to another. He even designed terminals with which to carry the current of electricity to the lime conductor, with the idea of making a lamp based on this principle. It is safe to say that were it possible to produce electricity as cheaply then as now, lamps of the Nernst type would have been known commercially much sooner than they were, for Jablochkoff's persistent attempts at commercial exploitation were baffled largely by the undeveloped state of electrical engineering.

That the rare earth oxides are exceedingly refractory and do not readily vaporize at high temperatures makes the Welsbach mantle possible; that these oxides will conduct electricity when hot makes the Nernst lamp possible. Of all the oxides which conduct electricity but few are refractory enough for an efficient filament or glower. It was in determining the most desirable of these and in fixing the best proportions to use that Nernst did his greatest work.

Ordinary red iron oxide, when formed into filaments and baked, will conduct electricity at ordinary temperatures, but such filaments do not withstand sufficiently high temperatures to be used as light sources. Magnesia and thoria, on the other hand, withstand exceedingly high temperatures, but these conduct electricity only with great difficulty. In general, mixtures of two or more oxides conduct better than a single oxide, and, in turn, the fusing point of the mixture is lower than that of either oxide alone. It seems that the vaporizing point is not necessarily lowered, judging from the fact that thoria and the small amount of ceria used in a Welsbach mantle, form quite a stable mixture, or possibly a chemical combination, while ceria alone or uncom-

bined is a somewhat undesirable oxide from its rather marked tendency to vaporize.

It would be a long story to take up the various properties of all the rare earth oxides and the possible combinations with one or more of the others. A mixture which is used largely in lamps of the Nernst type, is composed of 85% zirconium oxide to 15% of yttria earths. Zirconium is not properly classified among the rare earths, though it is customary to do so. The term "yttria," as used here, means in reality a mixture of many oxides occurring together in certain minerals and closely allied in physical and chemical properties, Zirconia was used in comparatively large quantities for the first Welsbach mantles, and hence, considerable attention had been given to various methods of producing it for such use. While many of the experimental glowers were made from zirconia bought from chemical supply houses, it was impossible to obtain uniform results from such material. Good zircon ore, which is a zirconium silicate, occurs in abundance in Henderson County, North Carolina, and this ore contains about 67% of zirconium as oxide. By treating this ore in the following manner, quite uniform results are possible:—

The ore is ground very fine in a ball mill and mixed with twice its weight of crude acid potassium fluoride. This is placed in an ordinary graphite crucible and heated slowly until thoroughly fused, and the ore is completely dissolved. The fused mass is then ground and dissolved in hot water containing a quantity of crude hydro-fluoric acid equal to about one-tenth the weight of the fused mass. The silica remains undissolved as potassium silico-fluoride (K_2SiFl_6) and the potassium zirconium fluoride (K_2ZrFl_6) is drained off while boiling hot into a silver lined vessel. Upon cooling, the filtrate develops crystals of potassium zirconium fluoride, and, doubtless, small quantities of other elements in similar crystal form. Iron and many other impurities which are present in the ore, or have been introduced by the use of crude reagents, remain in the liquor which is drained from the crystals. The crystallizing process may be much hastened by artificial cooling. Rinsing the crystals with cold water is likewise beneficial in removing all traces of the mother liquor. The crystals are gathered and fused in a platinum dish. By this

means, any silica present seems to be vaporized off, and other impurities, like titanium, are made insoluble. The fused mass is ground and dissolved in hot water and crystallized as before. A few of the first crystals are removed; or, instead, alcohol may be added to the solution until a small amount of crystalline precipitate is formed. These first crystals contain much of the undesirable impurities. They are, therefore, removed and the crystallizing process is continued. The pure crystals are then dissolved in hot water and the solution is made rather acid by the addition of pure hydrofluoric acid. Ammonia is now carefully added to the hot solution until a small amount of precipitate is formed. If the solution of crystals has been made acid, the addition of ammonia, even until alkaline, will precipitate out iron and some other foreign metals but will leave the zirconia in solution until it is cooled and diluted.

This method was found to be an exceedingly simple one for removing iron from zirconia, which, by other methods, is a troublesome operation. The hot filtrate, after removing the precipitate of iron, is dropped directly into a cold ammonia solution which at once precipitates zirconia as a hydrate. Up to this stage of the process, it has been necessary to use vessels and utensils not affected by hydrofluoric acid. The last precipitate may be made in glass or wooden receptacles. The precipitate is washed several times by decantation, and then pressed out on suction filters and after a thorough drying by heat is powdered and sifted through fine bolting cloth and is then ignited in a platinum dish, over a very gradually increasing temperature and with constant stirring. The ignition process requires several hours, or sometimes days, the final temperature being a good red heat. Traces of silica are removed by this operation.

The physical condition of the precipitate is dependent to a great extent upon the amount of hydrofluoric acid in excess. When precipitated from an almost neutral solution, the precipitate dries into hard pieces translucent in appearance, and which are difficult to pulverize. With the greater excess of acid, the material dries in lumps resembling starch, in which condition it is much more suited to our puropse.

The zirconium made by this process seems to be reasonably

pure. Precautions must be taken to keep out dirt, and to that end it has been found advantageous to purify the air admitted to the rooms where the glower materials are prepared by passing it through a water spray. An absolutely pure zirconia is not required and though a trace of silica improves the efficiency and seems to diminish the initial depreciation of candle power of a glower, it is a dangerous element to have present, for slightly more than a trace will cause a rapid change in potential difference at the glower terminals besides causing lack of uniformity in the behavior of glowers of one batch, due to the fact that the silica becomes unevenly distributed among the glowers by vaporization and condensation occuring in a roasting process, which will be described later.

Although the purest materials make the best glowers for direct current, it cannot be said that an absolutely pure zirconia is desirable for alternating current glowers. Silica is particularly undesirable in direct current glowers. In general, a glower which operates well on direct current, showing almost no change in potential difference, will show a greater change when operated upon an alternating current circuit.

The purity of the zirconia may be controlled, to some extent, by the number of times the material is crystallized during the purifying process, though each operation is attended with some loss of material. Physical properties are quite as important as chemical properties and the procedure above described was evolved to give proper physical, as well as chemical, properties to the material.

After all, "Handsome is as handsome does"— and the real test for the glower material lies in its ability to make good glowers. Test glowers have been made from hundreds of lots of zirconia and these tests, together with careful chemical records of each lot, have been the guide in developing the chemical process necessary for the production of good glowers. For direct current glowers, a crystallizing process is also considerably used, but from a solution of zirconia in hot dilute hydrochloric acid. After two or three such crystallizations, it is necessary to precipitate from a hydrofluoric acid solution, as in the first process, to get the material into proper physical shape.

As to the yttria used, this is principally obtained from the minerals gadolinite or yttrialite. Gadolinite is found in Norway and Sweden, and also in Llano County, Texas. The Texas deposit seems to be confined to a very small district and there is every evidence that it is a result of a volcanic eruption. It is found in crystalline form associated with yttrialite, cyrtolite, fergusonite, rowlandite, allanite, and other minerals. The ores from the Llano County district are radio-active and the presence of a pocket in the quartz is generally indicated by bluish discolorations radiating from the pocket through some distance of the surrounding quartz. It is also claimed that the ores contain small quantities of confined helium gas. Gadolinite contains, roughly, 42 to 45% of yttria earths, 23% of silica, 13% iron as oxide, and 9 to 12% of beryllia. Yttrialite contains 43 to 47% yttria earths, 30% silica, 5 to 6% ceria, didymia, and lanthan, as well as small percentages of urania. Fergusonite contains 32 to 42% yttria earths, 32 to 46% niobia. Rowlandite contains 47 to 62% yttria earths, 26% silica, and small percentages of iron and magnesia. Allanite contains 26% ceria and didymia, with a small percentage of yttria earths and considerable percentages of iron, calcia, and alumina.

It is a comparatively simple matter to obtain and purify the yttria earths from gadolinite and yttrialite so that they are suitable for glower making. About one thousand (1,000) grams of ground ore are dissolved in crude aqua regia. The residue is filtered off and the solution evaporated to dryness, repeating this operation several times, or until all silica is removed. The neutral solution is then diluted to several liters and the addition of a hot solution of oxalic acid to the hot solution containing the earths, brings down the rare earths as oxalates, leaving iron and other impurities in solution. The oxalate is washed thoroughly with hot water and ignited, and the crude yttria earths are dissolved in dilute hydrochloric acid, just sufficient in amount to dissolve the oxide. To the rather dilute and neutral solution, which is cold, crystals of potassium sulphate are added in excess. After standing twenty-four (24) hours, the cerium group has been quite thoroughly separated as double sulphates and the filtrate is then treated with ammonia to bring down the hydrates of the rare earths, thus freeing them of the great excess of potassium

sulphate. The washed precipitate is dissolved in a quantity of pure hydrochloric acid just sufficient to dissolve it, and again treated with boiling oxalic acid solution, as before. This brings down the rare earth oxalates in sufficiently pure form. The oxalates are thoroughly washed with hot water and ignited, and any remaining potassium is separated from the ignited oxides by washing upon a filter with hot water.

With the yttria, as well as the zirconia, physical properties are important, and the oxalate method gives an exceedingly fine precipitate which requires no mechanical treatment.

Experiments indicate that the yttria earths of the greatest atomic weights give the most satisfactory results in glowers. In other words, ytterbia is better than yttria. Owing, however, to the great difficulty of separating the yttria earths from each other, which is so far possible only by laborious fractionation processes, entailing great losses, not much has been done toward using the higher atomic weight yttria earths beyond selecting ores which are rich in these earths.

The Llano County ores seem to be superior to the foreign ores in this respect, the atomic weights being

Yttrialite	115
Rowlandite	107
Fergusonite	103
Gadolinite	100

while the foreign ores may be as low as 90 or 92.

The zirconia and yttria earths mixed in the proportions given above; namely, about 85 and 15, or 90 and 10, and about 5% of starch or gum tragacanth, are thoroughly mixed and kneaded into a hard dough and squirted by pressure through a die of proper size. This string, as it may be called, is dried and then broken into suitable lengths which are roasted to an intense white heat in a platinum box. The pieces are then ready to have terminals placed upon them.

A Nernst terminal is made by winding stranded platinum wire about the end of the stick of material and then pasting over with a paste composed of ground glowers and zirconium chloride, thus forming a hard cement.

The Hanks terminal has the platinum embedded in the glower material, the operation being carried on by the aid of an electric arc in which the glower material is fused.

Certain it is that the mode of conducting the current is electrolytic in character. The specific resistance varies with the relative proportions of the constituents. In order to obtain glowers of the same specific resistance, when using yttria earths of high atomic weights, as when low atomic weight earths are used, it is necessary to have the presence of the higher atomic weight materials in proportion to the atomic weights.

Upon direct current circuits, the positive end of a glower generally runs much hotter than the negative end, and a black discoloration appears at the negative end, especially if impurities are present. In fact, this is one of the most certain indications of the presence of an impurity.

A glower operated in vacuum soon destroys the vacuum, probably due to oxygen gas liberated by electrolytic action. That all the current is carried by electrolytic means seems incredible, for the current carried per square unit of cross section is far greater than can easily be accounted for by our usual conceptions of electrolytic laws. For example,—upon direct current and calculated by electro-chemical equivalents, the entire glower would be decomposed into the constituent elements in a very few minutes. Doubtless electrolytic decomposition and recombination do take place, but is it possible to account for the entire transport of current in this way? The assumption that the current is all so carried seems unnecessary in view of what is known of the power of highly incandescent bodies to ionize air to render it conducting. The air in the neighborhood of a glower is conducting, and to such an extent that the leakage currents from glower to heater had to be reckoned with early in the experimental work, and the difficulty was obviated by the use of a double pole cut out which disconnected the heaters completely from electrical connection with the remainder of the lamp after the glower started.

In connection with these speculations as to the real nature of the process by which the current traverses the glower, it is a fact that glowers which have operated for even a short time upon

direct current, will, when the current strength is diminished sufficiently to maintain the glower at only a good red heat, explode with considerable violence. This may be accounted for by considering that the conductivity at low temperatures is insufficient to ionize the surrounding and contained gases. The means of conducting the current then being largely electrolytic in character, the combination of the products of electrolytic decomposition cannot so readily take place, since the ions cannot so readily traverse the length of the glower to combine at the lower temperature; consequently disruption occurs.

The suggestion that has so often been made; namely, that the current be reversed in direction at intervals, as, for instance, every time the lamp is started, is altogether impracticable for the reason that a glower once operated upon direct current must never have its poles reversed, for a reversal means almost instant disruption. The potential difference across the terminals of the glower immediately after such a reversal is lower, indicating something analagous to polarization effects as we know them in aquous electrolytes.

In general, with the Nernst terminal, the potential difference across the glower at the normal current value is the same with alternating or direct current. With the Hanks terminal, or embedded type, the potential difference with direct current may be as much as 20 volts lower. The Hanks terminal will operate on direct current, but not satisfactorily as a commercial proposition. The life of the alternating current glowers is greater upon high frequencies than upon low frequencies, again suggesting electrolytic conductivity, at least in part.

The small glowers, up to 0.5 ampere, are made solid in cross section, the largest ones are generally made tubular; and, in fact, one ampere glowers must be made so. The reason for this is not that greater efficiency is sought by increasing the ratio of surface to volume, which is of course a fallacy, but inasmuch as the glower possesses a decided negative temperature coefficient as regards electrical conductivity, the center of a large glower would become molten before the outside surface reached an efficient temperature, the center being the better conductor. Glowers which have been greatly over-run, often exhibit this truth by the

appearance of a nodule of molten material which has spurted out to the surface.

GLOWER IN VACUUM.

A glower will operate in vacuum but the vacuum rapidly deteriorates, as before stated. A blue aurora or luminous haze surrounds the glower thus operated, either with direct or alternating current, and has been thought to be due in some way to vaporized metal (zirconium or yttrium) recombining with the slight amount of oxygen liberated. This idea seems plausible from the fact that objects such as wire or glass near the glower becomes coated with a white deposit of the glower oxides in a comparatively short time.

It would seem that oxygen necessarily plays a part in conducting the current, for a glower in an atmosphere of hydrogen or nitrogen behaves similarly to the one operated in a vacuum. In carbon monoxide or dioxide the glower exhibits the same characteristics as in air. The glower operated in vacuum exhibits a peculiar sluggishness in responding to changes in voltage at its terminals.

A commercial glower must operate at a high temperature to be efficient. Nernst glowers operate at about 2,300 C., it is supposed from determinations made by photometric means, and at about twice the efficiency of a carbon incandescent lamp. The spectrum of a glower is a continuous one and no evidences of selective emission in any particular region are noted. During the life of a glower, which averages about 800 hours under normal conditions of manufacture and voltage regulation, a depreciation of candle power takes place due to a number of causes. In the first place, all oxides of the rare earths do depreciate rather rapidly in light intensity per unit of surface at any given temperature. This is true even when heated by gas or electricity, and a platinum plate coated on one side with rare earths and heated from the rear by an ox-hydrogen flame behaves similarly. It is an inherent property of these oxides and a depreciation of 10 or 20% may occur during the first hour. There is then a slow diminuation of intensity of light, also inherent, and seemingly accompanying the tendency of the glower to change from an amorphus to a crystalline structure. A rise of potential differ-

ence across the glower terminals is usual, though it is possible to counteract this tendency, at least in part. The effect of a rise in potential difference, obviously, is to diminish the intensity of light by permitting less current to traverse the glower, running on a constant potential circuit.

With carbon incandescent lamps, the useful life or smashing point is considered to be that number of lamp hours during which the candle power decreases 20% from the initial candle power. Nernst lamps are similarly rated, counting as initial candle power that measured after the initial decrease above mentioned.

Other causes of depreciation in candle power are blackening of the enclosing glassware and reflecting surfaces. In this connection, the blackening is due largely to platinum which has been vaporized and deposited upon these surfaces. It has been found that the purest platinum is far better than that containing iridium or other of the platinum group, since pure platinum vaporizes much more slowly than alloys with these other metals.

It is to produce uniform chemicals and glowers in which the tendency to depreciate in light intensity and increase in potential difference shall be a minimum, that makes the problem so intricate and so fascinating, and still capable of much improvement.

Curiously enough, not the least of the problems to be solved in the development of the Nernst lamp was to overcome the tendency of porcelains to conduct electricity, the very property which in the case of the rare earths made such a lamp as the Nernst possible. A heater is necessary to start the glower. The heater is made by winding fine platinum wire upon a porcelain tube. It was necessary to produce a suitable porcelain which would withstand the high temperature necessary, and at the same time not conduct electricity. A porcelain composed of kaolin, alumina and silica is sufficiently refractory and porous to withstand the heat, and is an almost perfect non-conductor at high temperatures. The porcelain piece upon which the glowers and heaters are mounted is also of the same composition.

Another form of heater used more abroad than in this country is helical in shape and the glower is mounted in its

axis. This is made of pure kaolin and after squirting into tubes about a millimeter in diameter and winding with fine platinum wire and covering over the wire with a paste, the small tube is bent into a helix upon a mandrel, a pointed blow pipe flame playing upon the kaolin tube at the point where it bends onto the mandrel.

POSSIBILITIES OF SELF-STARTING FILAMENTS.

Many oxides will conduct at room temperature. A mixture of iron and tin oxides, about 70 iron to 30 tin, will start without preliminary heating and withstands rather a high temperature. There are many other similar combinations, likewise other possibilities exist; such as carbides, silicides and borides, operated either in vacuum or gases.

A Nernst glower may be made to conduct current at low temperatures by running it for a short time in a rarefied atmosphere containing a carbon gas. If to a globe in which a glower is operating in a good vacuum, an amount of hydro-carbon gas is admitted sufficient to lower the vacuum even less than a millimeter, the potential difference across the terminals of the glower will decrease rather rapidly and in the space of a few minutes, or even seconds, the glower will have become a conductor when cold. Or, in other words, self-starting.

The following experiment was tried:—

A glower was mounted in a glass bulb and in the axis of a carbon filament of a helical shape. The bulb was exhausted well and sealed off. The carbon filament was used four or five times to start the glower, alternating current being employed. After the glower had run a few hours, it was noted that it was changing color at its terminals. The discoloration gradually crept toward the center and after about twenty-four hours the glower could then be started without preliminary heating. Apparently enough of the carbon filament was oxidized during the short time it was in use to give a slight quantity of free carbon monoxide in the bulb, the source of oxygen being the glower itself.

It is uncertain whether this gas was effective in reducing some of the glower material to its metallic form, or whether a conducting carbide was formed by the action of the carbon gas

upon the glower materials. The former explanation seems preferable for the reason that it is noticed that the darkened portion at the negative end of direct current glowers is of higher conductivity than the glower proper, and it seems quite likely that this deposit is a metal separated out by electrolytic action. Metallic zirconium, for example, withstands very high temperatures in the open air without oxidizing and its melting and vaporizing points where air is excluded, must be very high.

Many possibilities exist, such as are suggested by the above experiments, and many of them have been tried. Boron carbide, for example, withstands very high temperatures and is a conductor while cold, though it seems to vaporize somewhat too rapidly; at least this was the case with samples tried which probably were not very pure.

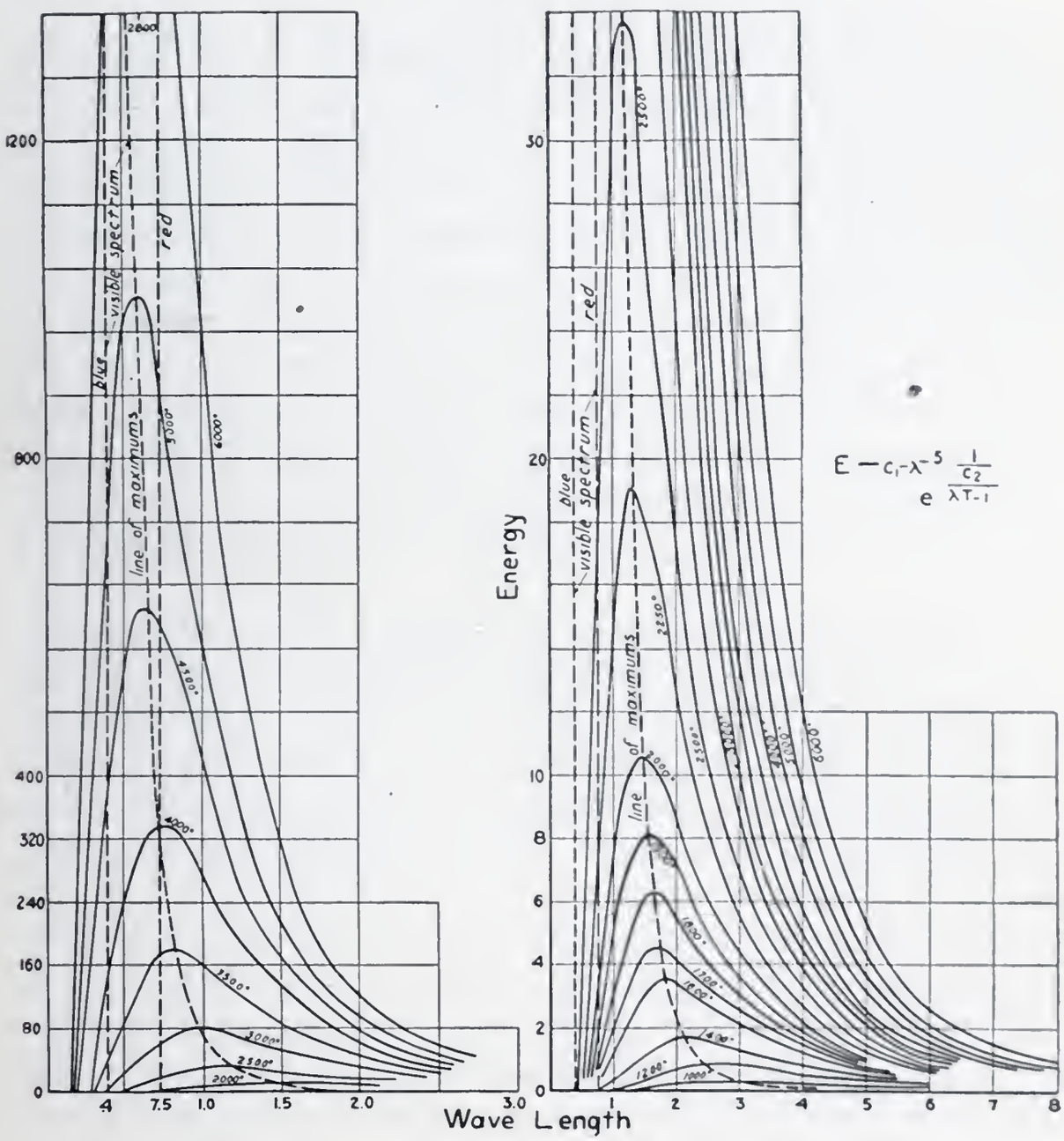
A Nernst glower, as well as those composed of thoria, magnesia and almost any of the refractory oxides, may be made conducting by treatment with a hydro-carbon gas. Sodium and potassium vapor also effect a reduction to the self-starting condition though not generally so readily as carbon.

There is a broad field still open and much that is not known of the properties of the rare metals. Oftener than not the supposedly pure metal is very impure, and the properties generally ascribed to it are in reality those of its carbide or other little known combination. Note the difference in properties of pure iron and iron containing even less than 1% of carbon. Is it not a fact that almost nothing is known of the physical properties of the rare metals? A good example of this point, and one bearing directly on our subject, is the recently developed tantalum lamp, the filament of which is a fine thread of tantalum metal. Tantalum metal until recently was not known to possess properties which now make it a promising addition to electric illuminants.

More or less experimental work has been done, particularly in Europe, in using the rare earths in electric arcs with the idea of obtaining better efficiency and more pleasing light. Lamps have even been tried with electrodes composed entirely of the rare earth oxides, though at the present time the greatest advances in arc lighting are being made along the lines of intro-

ducing such elements as boron and titanium into the electrodes.

In conclusion, your attention is directed to a curve which has been plotted to show the relation between the temperature and the energy radiated in the various wave lengths of light for incandescent bodies. We are apparently at the present time just on the border of the possibilities.



GOVERNMENT WORK IN FORESTRY.*

BY O. W. PRICE,
Associate Forester, Bureau of Forestry.
Non-Member.

It is not always that the Bureau of Forestry has a chance to be heard before those who, from the very community of their interests, are in sympathy with its work —as I venture to assume, are the members of the Engineers' Society of Western Pennsylvania. And that fact makes it particularly pleasant for me to say a word to you about the Government work in forestry. There is a good deal regarding it, which I cannot tell you in the time at our disposal, because the Bureau of Forestry, or the Forest Service as it is soon to be called, covers a very broad field of activity. But I shall try at least, to give you a definite idea of the main lines of the government forest work, of its policy, and of the kind of results that it aims at.

For the coming fiscal year, the Bureau will have an appropriation of nearly $900,000, and about 800 members. Six years ago the Bureau was a Division, with an annual appropriation of about $20,000, and a membership of 10. At that time the conservative use of the forest on a large scale by the private owner was unknown in this country. National and State forest policy was in the formative stage, and its actual application on the ground had scarcely begun. The Division of Forestry thus faced the task of developing a nearly unexplored field. It took up its work with the belief that forest owners and users of forests products want not merely propaganda, but proof of the advantages of forestry, and that they are not going to change their methods until they are shown that it pays to do so. To this end, we are trying to meet great forest problems on their own ground by practical field work, and we are publishing their solution for the benefit of all.

*Read at meeting of the Structural Section, February 28, 1905.

The work of the Bureau of Forestry is of these four main kinds:—

It coöperates by practical assistance and advice, in forest work which not only benefits individual co-operators, but is of help to many others;

It attacks, independently, those urgent forest problems of national importance;

It administers the National forest reserves; and finally,

It publishes and distributes the results of its investigations.

Now let us run quickly over what the Bureau is doing in each one of these main lines of its activity. Its coöperative work is a powerful influence in bringing about the application of practical forestry to private lands. It comprises a definite offer by the Government, through the Bureau of Forestry, to coöperate with the owner of forest land, whether a woodlot of a few acres or a timber tract of a million or more, in the study needed to reach a comprehensive plan for the conservative management of the forest. This work is done under an arrangement by which the Bureau directs the work and pays part of its cost. The results are used by the forest owner in coöperation with whom the study was made, in applying conservative management to his forest. They are also used for publication by the Bureau, and therein lies the wide value of the coöperative work. For in this way we are able to put in the hands of many forest owners recommendations for the management of a tract which in essential conditions is similar to their own, and thus to spread broadcast a knowledge not only of the advantages, but also of the practical methods, of forestry.

So effective was the coöperative work of the Bureau in forest management, that it led to an offer of similar assistance in tree planting, which has also met with great success. The latter has been particularly valuable in encouraging tree planting upon the treeless plains of the West, where they are so urgently needed, both as protection against wind and snow, and also for the production of wood for farm uses. And the coöperative work now offers assistance also in studies of the most conservative and profitable methods for the use of the products of the forest. Among these are the studies which the Bureau is making in coöperation

with railroad companies, to find the best methods of seasoning railroad and construction timbers and lengthening their life by preservative treatment; its studies to develop methods of turpentine orcharding which will ensue permanence to the naval stores industry; and in many other ways, investigations aimed at economy in the use of forest products. As the direct result of its coöperative studies with private forest owners, the Bureau has undertaken along similar lines coöperative studies with States. For example, we have just completed a forest study in coöperation with California, under an appropriation of $15,000 by the State and a similar expenditure by the Bureau. This study was made to provide a basis for effective state forest legislation—for the institution of a definite and comprehensive state forest policy. In many states there is a praiseworthy desire to make the best use of the forest, but the knowledge is largely or entirely lacking as to how this may best be done. Few states have been so fortunate as Pennsylvania, in having a Forest Commission which could meet state forest problems effectively on their own ground. The result has been, that a great deal of state forest legislation has been enacted which, although excellent in purpose, is entirely inadequate to meet the needs of the case. Laws affecting the forest and its use have been passed without a sufficient knowledge of the conditions which they were intended to remedy. It is just this situation that the state coöperative studies of the Bureau aim to correct. Under this coöperation, a thorough study on the ground is made of the urgent forest problems which confront the state, and its results are used in drafting effective forest legislation suited to local needs and in organizing a state forest service along practical lines.

The coöperative work of the Bureau, in all its branches, has had two important results. It has been the means of getting forestry into effect in specific instances, and it has thus provided a series of object lessons of great and increasing value. The question may naturally occur to you;—Why should the government take up this work? Why should it not be handled by the private forester? And to that, the reply is, that there are no private foresters available to do it. It will be a very pleasant day for us when the coöperative work can be turned over to private forest-

ers in its entirety, because it will mean that practical forestry is definitely established as a private enterprise in this country, and not purely as a Government venture. But in the meantime, the Government is carrying the work because it is urgent work which permits no delay. The 500 million acres of private forest lands must continue to yield most of the country's timber supply. Their misuse is a national danger, their better use a national need.

The independent investigations of the Bureau include the study of those urgent forest problems which materially affect the development of the great industries dependent upon wood. It is obviously the duty of the government to map this country, because maps are essential to its development, and their preparation is generally beyond the means or the knowledge of the individual. In just the same way, it is a national duty to put in the hands of the people knowledge required for the best use of the forest and its resources, and unobtainable through private enterprise. The scientific work of the government throughout is attacking problems national in their importance whose solution is beyond the power of the individual. Under this policy the Bureau is making comprehensive studies of commercial trees, which are useful in plans for conservative forest management and to wood users generally. It is making practical studies of forest fires, upon which to base legislation against them and from which to derive effective measures for fighting them and preventing them, on the ground.

In a similar way, the timber tests now being made by the Bureau at four laboratories are yielding the knowledge of the strength of our commercial timbers without which the fullest economy in their use is impossible.

The forest yields and volume tables being prepared by the Bureau are in effect the tools, the necessary initial equipment, for conservative forest management in all parts of this country. In its forest maps, its dendrological studies, and in many other ways, it is providing the great industries dependent upon the forest with knowledge essential to their development.

Now let us turn to the third line of endeavor with which the Bureau is charged. Until February 1, 1905, the Bureau could, under the law, merely advise regarding the technical management

of the reserves. On that day, the bill transferring the forest reserves to the Department of Agriculture became law, thus consolidating the forest work of the government in the Department best equipped to handle it. The administration of the national forest reserves is no small matter. It comprises the care of over 60 million acres of forest land, all of which is west of the Mississippi River, and which is of great and increasing importance as a source of timber supply, for grazing, and above all for the conservation of the water upon which the future of our arid lands depends. The relation between forestry and irrigation in the West is vital and intimate. The irrigation law of the government which expends, as you are aware, several millions a year in great irrigation works under an arrangement by which the purchaser of irrigated lands will pay a tithe of the cost of irrigating it, is fruitless unless the water continues to run. And that it assuredly will not do, unless the head-waters of the streams which can be used to irrigate arid lands are protected. Unless these mountain forests are preserved, there will be periods of low water and periods of flood, characterized by a constantly diminishing annual stream flow. And we need scarcely go so far as to consider the effect of the forest in maintaining stream flow. We simply need to remember, and it is scarcely worth while to say that to a body such as this, because you are fully aware of it already, that the use of great reservoirs can be entirely nullified by their filling up with silt. And they inevitably will be filled up with silt through deposits from muddy streams, if these streams are not kept clear by the preservation of the forest cover upon their drainage basins. When we remember that the sucessful fulfillment of the irrigation policy of the government means perhaps 50 million acres more of fertile land in the United States, it brings forcibly home, the vital importance of our national forest reserves. The importance of the reserves to grazing, to the live stock industry, is direct and vast. A large part of the summer range is in forest reserves. The grazing grounds in forest reserves fed 2,450,000 head of stock last year. The forest reserves affect mining, because it is mainly from them that timbers used in the mines must come. They affect railroads through their influence upon the industries upon which the development of the transportation systems depends.

To sum up, the forest reserves furnish, and they alone can furnish, wood and water, the two things more essential than any others to the development of the West. How great the development of the West will be under the proper care and extension of the forest reserves, no man can say. But without that care, the development of the West will go backward instead of forward. The policy of the Forest Service in its administration of this great national forest property is, to devote it to the permanent well being of all, not to the temporary benefit of a few. The point of view which will animate the administration of the reserves is, that all their resources are for use. And where conflicting interests must be adjusted, and there are conflicting interests upon the reserves, as, for example, among sheepmen and cattlemen, the policy will be to decide the question always from the standpoint of the greatest good for the greatest number in the long run. Such an administration is not possible by the mere promulgation of general orders from Washington. It is possible only through the settlement of local questions on local grounds and only after a thorough knowledge of local conditions has been obtained. And this is the way in which the Bureau is going at the work.

Under the fourth line of endeavor, the publication and distribution of the results of its investigations, the Bureau is getting the knowledge it gathers before the people in its bulletins, in what we are trying to make a simple and direct form. The publications are going out and they are being read and used. The aim of the Bureau is, that they shall contain not material of purely scientific value, but practical recommendations for the best use of the forest and its products, based on thorough study.

It is by work along the four main lines which I have outlined that the Bureau is taking advantage of its great opportunity. In six years it has sprung from a little known organization to be the compelling force behind the movement toward a better use of our forests. It has grown rapidly, and its achievement has been definite and far reaching. But the volume of the work done is insignificant compared with the volume of the work still to do. In my judgment, the Bureau has done its work, and it possesses its power of still more important work in the future, above all because it is practical in its aims. It considers not only the preser-

vation of the forest but also the preservation of the industries dependent upon the forest, because its policy is to help rather than to hinder. And right there, I want to emphasize as strongly as I can, that so far as its resources permit the Bureau stands ready to take up the forest problem confronting any one of you, for just so far as we can render practical assistance to you and other users of the forest and its products, just so far is the Bureau itself of use.

DISCUSSION.

Mr. Emil Swensson, Mem. Eng. So. W. Pa.—That forestry farming is a profitable business has been known for many years in Europe, although people there, the same as here, had to be taught it forcibly, by the disappearance of good timber.

With your permission I will tell of a couple of examples, showing what is done in profitable forestry farming in Scandinavia. The Swensson family, on my mother's side, came from the Jutland Peninsula of Denmark, in which country timber is and has been for several centuries exceedingly scarce. The wealthiest branch of her family has for over two centuries derived a very handsome support from the exclusive farming of a forest. I do not know now the amount of acreage contained in the farm, but it is entirely covered by a forest and kept in that condition at all times, cutting only a certain amount every year and replacing it by planting. It will take between 30 and 35 years to cut through the entire acreage, so that the cutting can begin anew on the new growth of matured trees, planted that long ago, and so on, continuously.

The local names on the west coast of Sweden indicate that centuries ago the entire country side was covered with forests, composed mainly of oak, beech, pine, elm and poplar. The land, however, has been bared of any kind of forestry growth for many years, and in consequence thereof, the sand on the ocean shore kept gradually covering up vegetation and driving it inland. In the memory of the last two or three generations many attempts were made at reclaiming the coast, by starting forest groves. All seemed in vain until about fifty years ago, the movement of the sand of the shore was checked by some species of a weed, which I

believe was wild rye. Behind the same, on the inland side, hawthorn, scrub-oak and similar hardy bushes were planted. About that time a society of school children was formed, called "The Friends of the Song Birds," which took the planting of trees energetically in hand. They had several planting days, similar to our Arbor Day, but it was not a case of planting for the love of it, it was compulsory on the part of the members of the Society, and, under their fostering care, large tracts of land are now covered with forests of various species, suitable to the difference of the soil. Belonging to the above society when a youngster, I helped to plant one of the groves, and when revisiting my native land in 1898, it so happened that the society, which was still alive and doing good work, had a monster picnic, in the very wood I had helped to plant.

In the lecture no mention was made of methods or means taken to preserve the acreage of forestry which the U. S. Government is reclaiming. I might mention that in Sweden the Forestry Bureau carefully watches over this feature of the subject. No timber can be cut without the permission of the Bureau and no timber marketed without its stamp, the stamp not only showing that it is with the Bureau's permission the tree was cut, but also that a sufficient number of plants have been put down to perpetuate the forest acreage and keep the amount of commercial lumber up to a fixed standard.

Mr. Harry J. Lewis, Mem. Eng. So. W. Pa.—My boyhood days were spent in Ohio among the hard wood and I have seen many attempts to use timber land for grazing by cutting out the underbrush and small trees and allowing the native blue grass to come in. The grass was far inferior to that which grew in the open and the trees, standing apart, became so wind-shaken as to carry very little good lumber. My observation would suggest that underbrush and leaf mould is almost as necessary to the maintenance of a hard wood forest area as the trees themselves.

Mr. O. W. Price—I agree with you. But the grazing in the forest reserves does not necessitate any brushing out. We manage the forest for its best use and take the mature trees out of it in such a way as to promote the growth of young trees to take their place. The grazing is confined for the most part to the meadows,

which are as you know a characteristic feature of the mountain forests of a large part of the west, and to the park-like forests which from natural causes only, are a good deal like the farmer's forest after he has brushed it out.

MR. E. K. MORSE, Mem. Eng. So. W. Pa.—I have always had the understanding that you should not allow sheep where you were raising forests, yet I noticed in your pictures large flocks of sheep on forest land.

MR. O. W. PRICE—There is no question but that sheep make heavier demands on the range than cattle. They graze much closer and there are more of them. And a closely herded band of sheep may sweep the ground as bare as the track of a fire. But we have got to have mutton and wool, and the reserves have got to help in producing them. Sheep can be grazed in forest reserves in such a way that the growth of the forest will not be injured. It is simply a matter of conservative grazing. There are some areas from which sheep should probably be excluded entirely. For example, those where the slopes are very steep and there is already very little covering. But elsewhere sheep grazing will continue under regulation. The question will be thoroughly studied on the ground and the number of sheep be alloted to a given reserve which can graze there without injury.

MR. EMIL SWENSSON—May I ask, Mr. Price, the difference in length of time that it will take to produce commercial timber, between timber that is grown in virgin forest and that which is grown on a forest farm?

MR. O. W. PRICE—For planted timber we have very little data in this country. Our plantations are seldom more than 20 to 25 years old. As a rule trees probably grow faster in a plantation than in a natural forest. The planted tree has a better regulated growing space and better light conditions. The growth of many trees in a natural forest is restricted by the shade cast by other trees.

MR. WILLIS WHITED, Mem. Eng. So. W. Pa.—Mr. Price says plantation forest grows more rapidly than virgin forest. As I understand it the strength of timber is about in proportion to its density. Is that timber as dense as what is grown in virgin forest?

MR. O. W. PRICE—I think in most cases the wood of trees from plantations will not be quite so dense, since it is faster grown. But I don't believe the difference is going to affect seriously the inherent qualities of the wood. You gain greatly in clearness, and absence of knots.

MR. RALPH CROOKER, Jr., Mem. Eng. So. W. Pa.—I have a friend who owns a large amount of land, set out in pine by his father. While I was visiting there he sold the stumpage on a piece of ground and on turning back to his father's books, found that thirty years before that same piece of land had been cut off. He figured the interest on the land value and found it had just netted him 6% for the whole time. When going through the property he pointed out to me pine he thought large enough to cut which was set out when he was a boy, and it was probably 12 to 15 inches diameter then. I think under such conditions pine grows at least ½" diameter in a year.

MR. O. W. PRICE—Under rather difficult conditions. We had that purely commercial planting is going to be done in the east on a large scale, as well as in the west. We have a very large relative area fit only for the production of timber. And where you can show a 6% investment it is certainly a wise thing to plant trees.

MR. F. C. IRVINE, Mem. Eng. So. W. Pa.—Mr. Price spoke of the cost of planting reserve as $3.00 an acre. Under what conditions?

MR. O. W. PRICE—Under rather difficult conditions. We had to establish our own nursery and seed beds, and get the seed from a great distance, but $3.00 is the actual average cost so far.

MR. F. C. IRVINE—How close do you plant the trees?

MR. O. W. PRICE—As I remember it, four feet.

MR. F. C. IRVINE—You have to thin them out, don't you?

MR. O. W. PRICE—They will thin themselves out. If you plant much farther than four feet apart you will simply get the sort of tree that grows in the open. It will have branches right down to the ground and it will not clear itself. In Germany, where they plant better than anywhere else that I know of, and get the best results in commercial planting, they scarcely ever plant more than one meter apart.

Mr. F. C. Irvine—Do you plant more than one tree in the same place, with the idea of thinning out if both grow?

Mr. O. W. Price—Only one.

Mr. Ralph Crooker, Jr.—Do you depend upon their shedding their own branches, or do you expect to go through and trim them?

Mr. O. W. Price—We expect them to shed their own branches. Pruning is an expensive operation, and by close planting trees will clear themselves and make straight grain and clear stuff.

Mr. Harry J. Lewis—I am reminded of a little plantation of about twenty acres in the black soil, treeless, prairie country of central Illinois. The trees are black walnut, planted primarily for a wind break, in drills about five feet apart and the trees originally two feet apart in the rows. In 1882 the trees were seven or eight years old and the largest about four inches diameter. About 1900 or eighteen years after, the trees had thinned themselves automatically, furnishing firewood meanwhile, the largest being about fourteen inches diameter at the butt. The canopy was fully forty feet high.

Mr. Willis Whited—I lived one summer in the northern part of Wisconsin in the pine region. That district impressed me as the saddest, the most prodigal, the most criminal waste of the resources of a wealthy country that could possibly be imagined. There was the great forest where you could go for a whole day on the train and see nothing but virgin forest, a solid mass of pine, the most magnificent pine forest in the world. That was twenty years ago. And just as fast as they go through that it is a barren waste. The trees which are not cut away are burned, and in place of the old pine trees it is grown up with some scrub-pine, a few hemlocks and an immense amount of birch that is practically useless so far as lumber is concerned. I would like to ask is it practicable to replace that white pine?

Mr. O. W. Price—I spent three weeks in that region last fall with Mr. Griffith, the state forester, and I saw a thing there that was very significant. The land now occupied by the Lac du Flambeau Indian Reservation, in the heart of the forest region of Northern Minnesota was lumbered about twenty years ago

for the first time. They took simply the cream of the timber. The rest of it was burned over and blown down so that now you could almost walk for miles without getting off the tree trunks. Now, twenty years after, they are going right back over that lumbered area and cutting out from fallen trees pine logs, which are still sound. That region of Northern Wisconsin is probably in worse shape as the result of fire than any other country in the United States, unless it be similar areas in Minnesota and Michigan. Those three states have a most difficult proposition to face from a forest point of view, because the areas are so completely denuded that there is practically no chance of reforesting them, except by planting. Fire has established almost desert conditions.

Mr. F. C. Irvine—Why does this land in Minnesota grow up in jack pine and hemlock instead of reproducing white pine?

Mr. O. W. Price—When you cut out the white pine and Norway, you remove most of the seed trees of those kinds. The species which take possession of the openings made are those left in greatest abundance, as for example, jack pine or hemlock, or hardwood. I have heard people ask "why is it that if you cut down a pine forest in Arkansas you will get an oak forest?" As a matter of fact, scrub-oak was there all the time, but so brushy and low, under the pine, that they did not notice it. Cut the pine down and the oak is more obvious, and it also grows faster after the pine is removed. In Minnesota, the change of species is the result both of decrease in the number of pine seed trees, and of changed light and soil conditions.

Mr. F. Z. Schellenberg, Mem. Eng. So. W. Pa.—Doesn't it require rotation of crops naturally or artificially? Is it not likely that the roots discharge something that is inimical to the continued growth of the species? Is it not likely that the soil is better adapted to a change?

Mr. O. W. Price—That is a most interesting question. But my personal feeling is that no rotation of the forest occurs unless conditions are changed. Take the mixed virgin forest, for example. Such a forest is a good deal like a world. It contains a good many people with different points of view, and with different characteristics. The reason they all stay there permanently is that each one has an advantage in one way or another. Take

the Southern Appalachians, the most remarkable forest we have in this country, and which contains nearly a hundred species in mixture. But one species never drives out another, unless man interferes. To determine why that does not happen is a very large problem, requiring the study of the life history of trees for its solution.

You will find in that region that the oak of one species or another grows in almost all situations. Thus oak has a strong advantage in its adaptibility. But on the other hand it is handicapped by the fact that it has a heavy seed which does not fall much beyond the spread of the crown. Also the acorns are eaten by squirrels and other small animals. Take the yellow poplar which grows only in good fresh soil. One might think it would be driven out in competition with other trees, but it will grow under comparatively heavy shade, while oak requires much light to develop well. Then again, yellow poplar has a light seed which is carried far by the winds. So it is, in every mixed forest, in which the balance of power is maintained by the varying characteristics of the trees. But as soon as man with his axe or any other outside influence changes local conditions, the balance is disturbed, and the composition of the forest changes. Thus a very large part of forestry is to know what the habits of each tree are, and hence to know what is going to happen after cuttings and to modify them to obtain the desired result.

But with regard to rotation of trees in the forest, my opinion is that you will find on the ground exactly what will grow best there. As soon as you interfere, other kinds of trees come in, because you have invited them by changed conditions. But I don't think you find a rotation of different trees in a virgin forest any more than in any other virgin form of vegetable growth.

Mr. E. K. Morse—We have laws in this state regarding the preservation of our forestry and the reclaiming of it, and we all know, as hunters and fishers, that there is enough forest left yet to get lost in. This state is slowly but systematically adding to her forest reserves, and the laws of the Commonwealth permit and provide for her buying certain acreage anywhere she may see fit to get it. The law provides that the price shall not be over $5.00 an acre. A great deal of the forestry that has been bought,

about 800,000 acres, has cost from 50 cents to a few dollars an acre. They have not enough money appropriated to carry it on properly. We are one of the greatest states to pass laws creating bureaus and then starve them to death. That is what they are doing with forestry. They are, however, in a few places trying to plant out and cultivate trees and take care of these forests in a proper and intelligent way. But that will never be properly done until we realize that it is a question of the almighty dollar. Then we will push it along with wonderful stress—if the forests do not disappear in the meantime.

We used to be very independent, but we are now reversing our point of view to meet the conditions, and it is painful. I remember years ago as a boy of sixteen, it was my province to take the oxen, or the horses, and go into the forest just south of Youngstown, Ohio, which was then virgin forest for miles square. It was no infrequent thing for me to load a four or five or even six foot oak. There isn't one of those trees left to-day. There is just one large poplar left in our section that I know of. And every time I go home I go with father all over that section. And if I live to be his age, 84, I expect to see trees and forests just as we see them in the old country. I have walked for hours and days in Germany where I would not be out of sight of trees planted in rows, beautiful trees just like the virgin forests we had here.

I have seen our white pine slaughtered until there are only two places I know to-day where I could find tracts. One in Clearfield County is some twelve miles square. That is the finest piece of timber I know of in this country. The other is near Penfield on the Low Grade Division.

As a boy I went with my father about thirty years ago over to Mercer. There was a swamp just this side where we pulled white pine and took them over to the farm and planted them. Last year I went over that farm and was surprised to find that of all the trees that we planted out, and there were several hundred of them, especially one row clear around the farm as a wind break, I only found one tree that would square less than twelve inches and cut from 15 to 20 feet in length. That is the reason that I said if I lived to be as old as my father I expected to see this whole country reclaimed.

I have never seen a charred tree, much less a fire, in Europe. Why is that? They are not more intelligent than we are, especially in rural districts. I can't answer unless it is due to the fact that we do not police our forests. How many of us passing along the edge of a forest and seeing a little fire starting would stop and get out of our carriage to put it out? I have been instrumental in cutting many thousand feet of timber, but it is only lately that I have been thinking of the future. It devolves on us, not necessarily engineers alone, but certainly as citizens of this Commonwealth and of the United States to do all that is in our power to help reclaim our forests that are so rapidly disappearing.

Mr. Emil Swensson—Referring to the forestry work done by the State of Penna., and adding to what Mr. Morse has already said, I wish to call attention to an article by Walter J. Christie, in the Pittsburgh papers, dated February 18, 1905, in which he says that the State Forestry Commission has decided to begin securing reservations in the western end of the State. So far the Commonwealth owns no land west of Clearfield County, because most of the territory in that end of the State is covered with oil, gas and mineral leases. There is considerable land along the upper Allegheny River water-shed, which can be obtained within the limits of the price the Commission can pay, namely: $5 per acre. This land is covered with leases as above, but the commission now believes it is necessary to depart from the old policy, in order to protect the water supply and begin the work of restoring the forests. Prior to January 1st, 1905, the State owned over 550,000 acres of land suitable for forest culture.

This land has been secured at an average cost of about $2 per acre. At present the State is not making much attempt to improve the reservations, as it will be necessary to first establish a number of nurseries. One is already in operation at Mont Alto, where thousands of white pine seedlings have been set out. At this place there is also an academy for the teaching of forestry. This academy has twenty pupils at present; the course being three years. After graduation all the students will be employed by the State in looking after these reservations. Some thought has been given to the necessity of bringing in foresters from Germany, where the science of forestry has reached the highest standard.

It seems that the intention is to finally properly man all the forestry reservations with foresters and their assistants.

A great interest has been taken of late in forestry in the State of Pennsylvania, the Governor's late message containing a clause on the subject, and it is well that it is so, as an immense acreage of mountain land through the State is now entirely useless, judging from the fact that no revenue is derived therefrom, when this is compared with the fact that in Germany where the forests are properly managed, the same are one of the greatest sources of revenue.

Engineers' Society of Western Pennsylvania.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS

The two hundred and fifty-fourth regular monthly meeting of the Engineers' Society of Western Pennsylvania was called to order in the lecture room of the Society's house, 410 Penn avenue, Pittsburg, Pa., at 8:15 P. M., Tuesday, April 18th, 1905, President Diescher in the chair and 53 members and visitors present.

The minutes of the last meeting being in print and in the hands of the members, on motion the reading thereof was dispensed with.

The report of the Board of Direction was read by the Secretary, recommending for membership the following applicants:

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
LEROY EDSON CARPENTER,	Foreman of Mechanical Draughting with the Union Switch and Signal Co. Swissvale, Pa. h. 908 Ramsey St., Wilkinsburg, Pa.	George P. Maury. Samuel Diescher.
WILLIAM BERNARD FULLER,	Genl. Mgr., of the T. A. Gillispie Co., Pittsburg Filtration Plant, 800 Westinghouse Bldg., Pittsburg, Pa.	Geo. T. Barnsley. Robt. Swan. Morris Knowles.
ARTHUR CHARLES KNICKERBOCKER,	Checker, Pressed Steel Car Co. h. 1418 Locust St., Allegheny, Pa.	G. A. Suckfield. F. B. Bissell. Thos. A. Collison.
EDWARD McGREW,	Partner in Engineering Firm of John Edward McGrew, h. Clayton Ave., Allegheny, Pa. 431 Fourth Avenue, Pittsburg, Pa.	F. Z. Schellenberg. Jos. A. Shinn. A. W. Patton.
RUSSELL HENNEN McMILLEN,	Chemist, Westinghouse Electric and Mfg. Co., East Pittsburg, Pa. h. 727 Hill Ave., Wilkinsburg, Pa.	T. D. Lynch. J. J. Crane. F. G. Ross.

On motion the Secretary was instructed to cast the ballot of the Society for the election of the above applicants.

The President announced the death of John Percival. On motion the President was ordered to appoint a committee of three members to draw up resolutions on his death.

The Board further submitted the following preamble and resolution and recommended their adoption:

WHEREAS, It is the duty of the members to aid in the progress of the Society, and one way in which this is done is by presenting interesting and carefully prepared papers. Be it,

"Resolved, That it is unwise to pass a vote of thanks to members who prepare and present papers, either before the Society meeting or at the various Sections, and that the presiding officer at all meetings is instructed to declare such motions out of order, unless referring to papers prepared by non-members."

MR. MORRIS KNOWLES—The matter came before the Board at its meeting Saturday evening and it appeared about in this way: The matter of extending a vote of thanks is always done, no matter what the value of the paper is and it has come to signify nothing, it is not usual in national societies and therefore it was thought wise to discontinue such practice. But it would mean something to a non-member, because he comes here under special invitation, while with a member of the Society it is his duty as a member. The Board were unanimous in the opinion that it is the wise thing to have such a resolution adopted.

MR. WILLIS WHITED—I am heartily opposed to that sort of thing. This vote of thanks is a matter of only ordinary courtesy. Sitting at your own table, if a member of your own family passes you something you say, "Thank you." Now it is as much of a duty to do that as it is for any member of this Society to read a paper, and I think it is very undignified not to say, "Thank you."

The motion to adopt the preamble and resolution offered by the Board was then put to vote and was duly carried.

The Board further recommended the adoption of the following resolution:

"Resolved, That we recommend to the Engineers' Society of Western Pennsylvania the adoption of a resolution asking the Bureau of Standards at Washington to take up the investigation of methods of Chemical Analysis, with the view to establish scientific and standard methods to be used in the examination of engineering materials."

On motion the resolution was adopted.

The Secretary read a letter from the Bureau of Forestry, asking the co-operation of the Society in some timber tests to be conducted by the Bureau.

On motion the president was instructed to appoint a committee of not less than fifteen, especially selected in regard to their fitness for giving information for conducting timber tests from a practical and professional standpoint.

Mr. Willis Whited, of the committee on name for new building, presented the following report:

"The Committee met and considered the list of names suggested, and beg to report that none of the names proposed appear to us to be satisfactory and worthy of a prize. We therefore recommend that the money be transferred to the Building Fund."

On motion the report was accepted.

Mr. Barnsley on behalf of the Reception Committee reported as follows:

Since the last regular meeting of the Society there was an excursion to the Duquesne Steel Plant on April 2nd. Two hundred of the members were met at the works by the officials of the Carnegie Company and piloted through the works and very handsomely treated in the general office at the conclusion of the inspection. The members expressed themselves as being especially well pleased, and I hope a resolution will be passed thanking the Carnegie Steel Company and the officials for their entertainment of us.

I have to announce that it has been arranged to hold a smoker at the Hotel Schenley on the 29th of this month. I want to specially request every member here to set aside that date and to speak of it to his fellow members as he meets them, and help the Committee to make the smoker a great success.

On motion the thanks of the Society were extended to the Duquesne Steel Company and to those officials who were instrumental in the entertainment of the Society.

Mr. D. A. Kohr then read a paper written by Mr. Houston Lowe on Factors that Affect Results in Painting. After discus-

sing the paper a vote of thanks was extended to Mr. Kohr and Mr. Lowe.

Meeting adjourned at 10 P. M.

F. V. McMullin,
Secretary.

MONTHLY MEETING OF BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at the Society's house, 410 Penn avenue, Pittsburg, Pa., Saturday, April 15th, 1905, at 8:15 P. M.

Present: Messrs. Lyons, Barnsley, Knowles, Frost, Morse, Maury, Schatz, Stucki and Secretary.

In the absence of the President Mr. Lyons took the chair.

Minutes of the preceding meeting were read and approved.

The following resignations were accepted: Otto Eisenschmil, Edward T. Parker, R. O. Belles, W. H. Cooper and Chas. A. Bacon.

Treasurer's report: Dormant fund, $3,500.00, checking account, $4,554.35.

Secretary's report: Total membership, 926; collections March 18th to April 15th, 1905, $942.75; Previously reported, $4,271.83; Total 1905 to date, $5,214.58; Payments to date during 1905, $2,733.90; Bills were paid by the Board amounting to $468.03.

Communication from the Chemical Section recommending that the Society ask the National Bureau of Standards to take up the investigation of the method of Chemical Analysis with the view to establishing scientific and standard methods of same, was, on motion, referred to the Society.

Communication from Structural Section enclosing letter from Mr. Pinchot, of the National Bureau of Forestry, was, on motion, referred to the Society with the recommendation that the Society appoint a Committee to co-operate with the Bureau.

Regarding a communication from Norwich University requesting a reduction in the price of Proceedings, the Secretary was instructed to write them asking for further particulars about their institution and whether they had any publication to give in exchange.

Committee on Registration Cards reported that they had the cards printed.

On motion the meeting adjourned at 9:30 P. M.

F. V. McMullin,
Secretary.

CHEMICAL SECTION.

The regular monthly meeting was held in the Society's house, Thursday evening, April twentieth, with the Pittsburg Section of the American Chemical Society.

The meeting was called to order at 8:25, Chairman G. P. Maury presiding. Twenty-nine members and visitors were present.

Mr. Abraham Gross read a paper on the "Value of Pure Food Legislation," and exhibited a collection of pure and adulterated flavoring-extracts, etc. After discussion the meeting on motion adjourned at 9:30.

Harrison W. Craver,
Secretary.

MECHANICAL SECTION.

The regular monthly meeting was held Tuesday evening, April 4th, 1905, at the Society's house, 410 Penn avenue, Pittsburg, Pa. The meeting was called to order by Chairman H. H. Anderson at 8:30 o'clock P. M., with 28 members and visitors present.

Mr. J. L. Moore read a paper on Superheated Steam.

Paper was discussed by Messrs. Stucki, James, Anderson, Fitts, Ely, Jennings, Diescher, Purdy and Emery.

Meeting adjourned at 10 P. M.

H. D. James,
Secretary M. S.

STRUCTURAL SECTION.

The regular monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held in the Society's house, 410 Penn avenue, Pittsburg, Pa., Tuesday evening, April 25, 1905.

Meeting called to order at 8:20 P. M. Chairman E. K. Morse in the chair, 36 members and visitors present.

Minutes of last meeting read and approved.

There being no unfinished business, committee reports, or new business, the chairman introduced the speaker of the evening, Mr. Frank R. Dravo (Member), who read a paper on "Concrete Lined Mine Shafts."

The discussion of the paper was participated in by the following members: E. K. Morse, Samuel Diescher, F. Z. Schellenberg, A. C. Beeson, Arnold Stucki, G. W. Schluederberg, and the speaker of the evening.

There being no further business before the Section, on motion adourned at 9:15 P. M.

T. J. Wilkerson,
Secretary S. S.

FACTORS THAT AFFECT RESULTS IN PAINTING.*

BY HOUSTON LOWE.

Non-Member.

When we were young in the paint business we fancied that if we could produce good material we would have no special troubles with it. However, experience soon dispelled this illusion and taught us that there are other things than the quality of the paint which affect the results to be obtained from its use.

The theme selected for our discussion is such a broad one that we cannot hope to treat the various phases of it in a comprehensive manner. However, we know that our thesis is sound, so we trust and believe that the Engineers' Society of Western Pennsylvania will help us prove it. Our personal experiences have been almost wholly limited to the testing of paint under such varying conditions as we have been able to find at our Works.

Substantial progress in the making and use of preservative and protective coatings for structural materials can only result from interchanges of thought and experience on the part of all those interested in their maintenance.

From our standpoint the following factors affect results in painting, viz.:

1st. The location of the structure, e. g., Seaboard or Inland.
2nd. The kind and condition of the surface.
3rd. The quality of the paint.
4th. The workmanship of the painters.
5th. The number of coats applied.
6th. The amount of time allowed to elapse between coats.
7th. The atmospheric conditions when the painting is done.

Location of Structure—Whether a paint is made to dry by oxidation, by evaporation, or by both, naturally there is a difference in its drying when used in the damp, saline atmosphere of the seashore or in the dry highlands of the interior; when used on the coast of the Gulf of Mexico or in the colder states of the

*Read by Mr. D. A. Kohr (Non-member) at meeting of the Society, April 18, 1905.

North; when used in the pure air of the country or in the vitiated air surrounding structures in many towns and cities. Not only is the drying of paint affected by the location of the structure upon which it is used, but its working properties and durability as well. The viscosity of oil and varnish being affected by temperature, they will work more easily in warm climates than in cold. The durability will always be impaired by alternate exposure to wind and water; by exposure to sunshine and rain-fall; deleterious gases, vapors and liquids; dampness, darkness, mechanical injury, etc.

The paint for the finishing or top covering of any structure should be made to meet the special conditions of exposure to which it is to be subjected. Competent paint-makers can readily make protective coverings to withstand any reasonable condition of exposure and use, but in order to do so, obviously they must know the conditions; e. g., we were recently called upon to make for a prominent railway system a steel tank coating to be used near the Gulf of Mexico. The engineer in charge informed us that there was so much water of condensation on the surface of the metal most of the time that it was only possible to paint between the hours of ten in the morning and three in the afternoon, and that he had to have a paint that would set (not dry and harden) in two hours, otherwise it would be impossible to secure fair adhesion. It was possible to make a paint to meet this condition; had we not known the condition, anything sent at haphazard would undoubtedly have proven a failure.

Kind and Condition of the Surface—Absorbent brick, soft lumber, corroded iron or a rough surface of any kind will generally require a paint with a larger proportion of liquids to solids than hard lumber, clean steel, tin, etc. In one case the paint will be more or less rooted into the material underneath, and in the other it must be held almost wholly by surface attraction. Lumber contains water, sap, ligno-cellulose, and mineral matter. The two former are repellent of paint. As a rule, the heart wood of trees is more receptive to paint than the sap wood, a notable exception being yellow pine, the sap wood of which costs less than the heart and takes paint better; therefore if protected by paint it will last longer in frame buildings. The railroad people who

are progressive have found this out, and are rapidly substituting sap wood for heart wood in freight car construction. We are surprised to learn that many reputable architects in the Southern States still specify the heart wood of yellow pine for siding upon houses of the best class; it is unfortunate that there seems to be a lack of understanding upon the part of educated men of the close relation which paint must bear to the surface which it covers, e. g., the wood, and the importance of specifying lumber that paint can stick to. There are said to be thirty-nine varieties of pine in the United States and numerous species of poplar, hemlock, cypress, etc., so that one can see that it is easier to design a paint for coating iron or steel than it is for coating wood. It may be a good idea to use common lumber or seconds for weather-boarding and then try to save it or hide it with paint, but we question the economy of it.

With metals, when their temperature is less than that of the surrounding atmosphere, more or less sweat or water of condensation will always be found upon them. This is repellent of paint, as also would be any grease that might in any way get on the surface. In other words, paint will only stick well to a receptive surface, and a warm and dry surface will certainly hold paint better than a greasy, cold or damp surface. It will also be noted that some metals not only hold paint better than others, but they also affect it differently. Paint does not adhere well to metallic zinc (galvanized iron). A paint spread upon clean metallic lead will dry much more quickly than one spread upon clean steel. On the other hand it will wear longer upon steel than it will upon metallic lead.

Another point regarding surfaces is this, viz., that rough surfaces hold paint better than smooth, and a paint upon rough surfaces seems to wear longer. The only reason for this phenomenon is that on a rough surface you get a greater thickness of layer than you do upon a smooth surface with the same number of coats.

The sand blast offers a rapid, efficient, and economical means of cleaning steel and putting its surface into a receptive condition for paint, and we would be glad to see this method of preparation more generally employed when painting contracts are

undertaken. So, too, we hope that it will not be long until architects, engineers, and builders realize that it is important to have sound, clear, dry lumber as a foundation for paint, and will insist upon the same in their specifications.

For an interesting paper on sand-blast cleaning of steel, with discussion by prominent engineers, the reader is referred to the "Transactions of the American Society of Civil Engineers," Vol. L, paper No. 948.

The Quality of the Paint—The quality of any paint depends as much upon its physical characteristics as it does upon its chemical composition, e. g., with two linseed oil paints that will show the same qualitative and quantitative analysis, the one of the greater viscosity will be the slower drying and the more durable of the two. This is because it will form a skin upon the surface that will be thicker and more impermeable to water and gases than the thinner paint. The corrosion of steel, the decay of wood, and the deterioration of paint are practically due to one and the same cause, viz., the combined action of carbon-dioxide and moist air. Therefore that paint or coating will give the best protection which will be least affected by and is the most impermeable to a combination of these two things.

To understand the nature of painting, we will first take up the subject of linseed oil, which, after centuries of use, to-day remains, from the standpoint of durability and drying, the best thinner we have for painting. Linseed oil in drying changes first into a sort of jelly and then into a solid leathery or rubber-like substance which Mulder named "Linoxyn." This linoxyn is a wonderfully tough and durable substance. However, when linseed oil is spread upon a smooth surface, without the use of pigment, the skin formed will be less than 1/1000 of an inch in thickness. Further, the skin so formed will be pervious to moisture. Pigment is therefore added to the oil for paint making, first for the purpose of thickening the skin formed, and second for the purpose of making the skin impervious to moisture. Dried paint may be looked upon as a fabric in which linoxyn is the chain and pigment the filler. Linoxyn is not quickly formed from linseed oil without dry air and light, but when once formed is much more stable and much better able to resist at-

mospheric influences than linseed oil itself. In other words, wet paint is much more sensitive than dried paint. A fair quality of linseed oil when spread out in a thin layer on a smooth surface under favorable conditions requires from five to seven days to dry and harden. As this would be too slow for practical purposes, paint-makers and painters either add to the oil some pigment that will react with it to hasten drying, or they add to it some oxidizing agent like japan or some diluent like spirits of turpentine or petroleum naphtha, the two latter only serving as volatile extenders that more or less interrupt the continuity of the resultant film. So many books have been written on the subject of linseed oil that we will not attempt to take more of your time in the discussion of its nature and characteristics, but should you wish to pursue your investigations further, it will be a pleasure to cite authorities.

We will now take up the subject of the pigment content of paint. From the practical standpoint, pigments may be divided into two general classes; first, those that react more or less with the binder, notably the carbonates and all lead compounds; and second, those that have no chemical action upon the binder, i. e., are inert, such as graphite, lamp black, barytes, silica, and sometimes ferric oxide, etc. Those of the former class produce the better drying and less durable paints; those of the latter class produce the slower drying and more durable paints. We work upon the theory that under coats should dry more quickly and harder than those above them, and that the difference in drying between adjoining coats should not be very great. On this theory, where best results are desired, we always recommend the use of red lead paint as a foundation coat on naked steel, and white lead paint as a foundation coat on bare wood. For the middle coat, where conditions will permit the use of three kinds of paint, we recommend the use of a paint made from about equal proportions of active and inactive pigments with linseed oil. For finishing coats we always recommend the use of paint made from inactive or inert pigments with linseed oil. Amongst the best of this class may be noted graphite, charcoal, oxide of iron, powdered mica and aluminum. The pigments named in this class are more stable and weather resist-

ing than linoxyn, therefore in the use of them you will find that the thicker your paints are the more durable will be the films resulting from their use when spread out in thin layers on steel. On the contrary, where durability is desirable, with active pigments like white lead, zinc white, etc., which are more affected by atmospheric influences than linoxyn, you will find that the thinner you use paints made from such pigments, consistent with fair covering of the surface, the better they will wear. On general principle or as a common law, we would state the proposition as follows, viz., where inert pigments are used with linseed oil the thicker your paints are, consistent with proper spreading under the brush, the better they will wear, and as a corollary to this, thin coatings, especially top ones, of paints made from pigments like white lead, chrome yellow, etc., will wear better than thick ones. You have doubtless noted how much better common paint, made from dull inert pigments, wears on freight cars, barns, bridges, etc., than more delicate colors, made from active pigments like white lead, etc., wear on line cars, frame houses, and structures of that class.

Workmanship of the Painters—A good painter will often get better results with a fair paint than a poor workman will get with a praiseworthy one. The method of application is about as important as the quality of the paint used, for the reason that a layer of air and the water which it may hold exists upon all surfaces. This layer of air prevents close adherence of the paint to the surface and it can only be gotten rid of by thoroughly brushing the paint out on to the surface and into the body of the material underneath.

A distinguished British painter and author writes: "The less paint that is put on at each operation consistently with a proper covering of the ground, the better will the ultimate result be." "Less paint and more painting," he impresses as a need "to quite 90% of his painter students." The personal equation always counts in painting as it does in almost everything else. From experiments with an ocular micrometer in connection with a microscope, we find that single coats of the same paint may vary in thickness from 1/500 to 1/1000 of an inch. The variations in thickness from these extremes and intermediate points

are due to the varying pressure of the brush under the hands of the painter. Much of the poor work done now-a-days results from the quality of the tools purchased by or supplied to the painters. We insist that a good workman to do good work must have good tools to work with; that is, brushes not over 3½ inches wide and full or thick with good stiff bristles. For the highest class of work we prefer what they call down East "Pound Brushes"; that is, round brushes with good stiff okatka bristles in them not less than 6 inches long. With one of these properly bridled, a painter can do more and better work in a day than it is possible for him to do with the ordinary flat brush that is usually furnished him and which costs little less. The good workman will always pay especial attention to the coating of edges, and those parts of a structure where water and dirt will lodge, and to the filling in of all crevices, beads and mouldings to prevent the incursion of water. These hidden parts are often the vital ones in bridges or in buildings of steel cage construction and they are those which should have the most vigilant and constant attention.

The Number of Coats Applied—The durability of paint will be affected by the number of coats applied, e. g., two coats of paint will wear better than one; three coats of paint will wear better than two; and four coats of paint will wear better than three.

The theory upon which we design coatings both for wood and for metal is, that the primer or foundation coat should be considered as structural material whose function is both to exclude air and moisture from the material underneath it and to form a receptive surface for subsequent coats. It is further our theory that in the sequence of coats this primer or foundation coat should dry more quickly and harder than any one covering it.

Where it is desired to finish a structure in white, or in a light tint composed largely of a white pigment, we have reason to infer that it is wise to limit the number of coatings applied to three, exclusive of the primer; the reason for this limitation being that our knowledge includes no inert pigment which when used alone with linseed oil will have sufficient hiding power to

serve as a satisfactory paint pigment. The consequence is that to produce a good paint in white or some light tint, it is necessary to use pigments like white lead or zinc white that react with the oil and continuously weaken it until its power as a binder is finally destroyed. With paints made from inert pigments and linseed oil it is undoubtedly true that, provided a sufficient interval be allowed to elapse after each coat for it to dry and harden, the greater the number of coats and the greater the total thickness of the layer, the greater will be the degree of impermeability to air and moisture, and also the greater the degree of resistance to atmospheric influences.

Andés, in his work on Anti-corrosive Paints, says: "It may be laid down as a normal standard that—presupposing the use of good paint—one bottoming coat and three subsequent coatings, laid on at suitable intervals, will be required to produce a layer of oil paint of sufficient thickness on iron to keep moisture away from the metal and to protect the latter from rust for a certain time."

The Amount of Time Allowed to Elapse Between Coats—Linseed oil in drying takes something from the air, viz., oxygen, and gives off something to the air, viz., carbon-dioxide and water. Mulder describes the process beautifully and calls it "the breathing of the drying oils." The things favorable to the drying of oil paints are light, pure, dry air, and moderate artificial heat. The things unfavorable to the drying of oil paints are a humid atmosphere, darkness, noxious gases, and low temperature.

The amount of time which should be allowed to elapse between coatings of any given oil paint will vary so much with the location of the structure, the kind and condition of the surface, the quality of the paint, the atmospheric conditions when the painting is done, and for the first few days after it is done, that it is obvious no set period of time can be named. However, a painter who is interested in his work can always determine whether one coating is fit to receive another by noting its luster, the time when the paint no longer sticks to the dry skin of the finger, and the time when the layer cannot be moved under heavy pressure. Blistering, cracking and peeling of paint are often due to the fact that under coats were too elastic when they were paint-

ed over. If a piece of work be painted coat upon coat of oil color before each coat is sufficiently dry, the movement and shifting of the under coats in their effort to obtain oxygen for their proper hardening will either rupture, i. e., crack the top coats, or lift them up in the form of blisters. Pearce in his excellent book on painting says that four days is not too much to allow for the proper drying of oil color which will nominally dry in twenty-four hours. The period may be shortened by additional dryers, but a good rule is to allow all paint to stand four times as long as it takes to arrive at superficial dryness.

The Atmospheric Conditions When the Painting is Done—Opinions as to the best time for painting differ largely, but nearly all the standard authorities concur in the opinion that a temperature of from 55 to 80 degrees, and an atmosphere that is as free from moisture as possible, favor the best results.

The atmospheric conditions vary so widely in different localities throughout the country that the student of painting can only reasonably draw inferences as to methods of securing the best results by close observation and persistent experimenting under as widely varying circumstances as possible. For instance, a certain paint would dry under average conditions in our laboratory in about five hours. The same paint out of doors under varying conditions dried as follows, namely: February 5th, in dry weather, temperature below zero, in 26 hours; February 28th, in dry weather, temperature about 50°, in 4 hours; March 7th, in rainy weather, temperature about 60°, in 22 hours; March 8th, in damp weather, temperature about 36°, in 14 hours.

It is our opinion that in painting it is always especially important to note the weather conditions the night before the painting is to be done. In the examination of reported failures of paint, experience has emphasized the relation of durability to atmospheric conditions, requiring a careful record of the weather the night before and the night after the work was done.

Sweat, or water of condensation, will always be found upon steel when its temperature is lower than that of the surrounding atmosphere. Simon made observations in the softening of paint by dew on the iron-work of bridges, the result being the formation of rust; he expresses the opinion that rusting is not attribu-

table to the iron's having been insufficiently cleansed before painting, but rather to the deposition of dew soon after the painting was done, the result being rapid cooling of the metal, the liquid being then absorbed by the paint and brought into contact with the iron, which is thereby rusted.

Before closing I wish to say that Mr. Lowe, who wrote this paper is not able to be here on account of sickness. He was in ill health when he prepared it and he wishes me to express to the Society his regret that he is unable to be present, and to assure you that he would consider it a great pleasure to be here.

DISCUSSION.

Mr. M. P. Wood, Non-Member (by letter)—The thorough cleaning of the metal before assembling the parts and painting them, is the basis for the preservation of the structure whatsoever it may be. Scores of years of recorded observations at the many Navy Yards in the world, have invariably shown that mill scale, is an active agent for the corrosion of fine bodies like copper. Even the close joining together of iron and steel of different qualities invariably inaugurates corrosion, as many cases of failure or collapse of structures have clearly shown. Until the same zealous care is exercised over the cleaning and painting of the metal as is given to the construction details by the superiors of the Engineering Corps in Shops, Railways and elsewhere, corrosion will prevail.

Reform must begin at the Engineering Shops and continue uninterruptedly from the rolling mill to the completed structure. Specifications for the painting of engineering materials are almost entirely ignored if they call for any extra labor on the part of the Engineer in charge, or increased cost to the owner. Poor Paddy with his greasy rag, or the painter with his ready brush gets the blame for the condition of work that should rest on those higher in authority.

Mr. J. N. Chester, Mem. Eng. So. W. Pa.—The most marked destruction of paint we have ever seen was in the Indiana gas and oil regions, where the houses presented the appearance, on the side from which the winds blew from the oil and gas wells,

of having been in close proximity to a fire, the paint turning dark and peeling off. And it attacked not only paint on wood, but paint on brick buildings as well. We have all, especially in the Pittsburg district, observed the effects met with along our rivers where the factories are belching forth great volumes of black smoke and sulphur, and in the vicinity of furnaces, where the fumes destroy our paints wherever they may be.

In our practice, that mostly of water works construction and operation, the great difficulty met with is to find a paint that is even reasonably good for the interior of steel tanks and stand pipes. While with some waters, especially the soft swamp waters, the paint will last for years, yet in the stronger alkali and acid waters—the acid reaching the maximum in the vicinity of Pittsburg and the alkali in some of the western states such as Kansas—a very short period will serve to remove every vestige of paint.

There are many good paints, and many poor ones. There are a few good painters and a few times that the paint is well applied, and fewer times that the surface is properly prepared, especially in steel work. No one knows until they get at it just how difficult it is to prepare these surfaces, and how much more difficult it is to get somebody else to prepare them for you.

Our metal for building tanks and other structural work, as it comes from the mill, invariably carries with it a mill scale and a grease covering that is an enemy to paint adhesion. We have tried many ways of overcoming this difficulty, and two have in our opinion proved fairly successful. One, by giving it a coat of light volatile oil and brushing with a rough brush, the other, by letting it rust and then removing that coat with a rough wire brush followed by a painter's dust brush ahead of the painting. This does not apply, however, to those inner surfaces of stand pipes and tanks where the action of the water is to remove the paint.

There are other difficulties, even after the surfaces are properly prepared and the work done conscientiously, especially around power stations and in the vicinity of railroads. The first coat is hardly applied before a locomotive scatters a shower of cinders on your fresh paint giving it the appearance of having

been sanded. Then when anything comes in contact with that cinder projection and rubs it off there is a space laid bare and it is just like the starting of a festering sore, it will spread, and sooner or later that structure will be covered with patches. And so far as we can see it is in a measure unavoidable.

We have trouble in getting paints for other purposes, interiors especially, also a paint without body for the water ends of pumping engines so that we can remove the nuts and cylinder heads and handle or repair these parts, and yet with body enough that when condensation takes place it will not bring the iron rust through and streak them. In an engine room, especially where the coal is poor, apply three coats of a white paint and in a short time it will look like whitewash, checking and cracking almost to the extent of peeling off.

Another place is the protection of pipe covering. After the asbestos work has been covered with canvas, apply one or two coats of a good stiff filler to the canvas and then apply a good enamel paint that will not crack or check, that will leave us a surface from which we can dust off the accumulation of the boiler and engine room and keep it clean. We can even extend that to the cylinders of smaller machines thus saving a wooden lagging that sooner or later chars, or a Russian iron lagging that dents with every touch of the wrench. While the lagging may be looked upon as more durable than canvas well filled and painted with enamel, yet if the covering could be accomplished in the way we have outlined it might be a saving.

Mr. D. A. Kohr—We have had troubles of our own in that Indiana field you have spoken of. We have found that it is due to the sulphur compounds in the natural gas which affect the white lead in the paint. We have gotten around it by using a zinc paint and we have no trouble except that sulphuric acid may be formed by the oxidation of the sulphur compounds, and it is out of the question to expect any organic substance to stand prolonged exposure to its action.

As to paints for the interior of tanks I would suggest that a varnish paint would be better than an oil paint. It is a pretty hard proposition though. Regarding the alkali and acid waters

that act on the paint, there is where the paint-makers should know something of the conditions before making the paint.

We have a paint that we applied to the heads of our boilers and the breechings. That paint has been on for six months and is good yet. You will find that varnish paints stand heat better than oil paints.

For covering canvas we would suggest a paint made of a long oil varnish. Such a paint will stand a great deal of expansion and contraction.

Mr. D. M. Howe, Mem. Eng. So. W. Pa.—Professor Sabin and myself were called in several years ago by the United States naval officials at the Brooklyn Navy Yard to make suggestions on cleaning the hulls of vessels. The Atlanta and the Chicago had just returned from a trip around the world, and if you ever saw the bottom of a vessel after she came from the tropics you will know the vast amount of filth that had accumulated, barnacles, dead sea grass, all kinds of dead vegetable matter and so forth. The bottom of the Atlanta has about 14,600 square feet of superficial area that had to be scraped and painted.

It took thirty men ten days to remove the accumulations from that area and then the scraper would not take off all the dead matter. We made the suggestion of the sand blast and it then became a question of cost between hand removal and the sand blast. They had the compressed air in the navy yard and we got two machines that had been brought over from London. We had two men at each machine and one laborer, that made five men that went to work with the hose on Monday morning at eight o'clock. By Saturday noon they had cleaned the 14,600 square feet of all accumulation and had applied one coat of paint. There was so much humidity in the air that in thirty minutes after the sand blast had removed the covering, looking through a powerful glass, you could see there was a rust forming the cleaning was so thorough, so they would clean 200 feet of surface and then apply the paint. There was 5½ days for 5 men against 10 days for 30 men. Then all the navy yards in the United States put in sand blast and they are now cleaning the bottoms of vessels by that method.

Dr. Walther Riddle, Mem. Eng. So. W. Pa.—Linseed oil in the shape that it comes to market has a considerable percentage of matter that is soluble in water. Of course if this is left in the oil the rain will dissolve it out leaving cracks in the surface. Any oil, to be properly used in paint, should be treated in such a way as to get rid of this soluble matter in order that as linoxyn is formed it will not produce cracks.

Mr. Willis Whited, Mem. Eng. So. W. Pa.—I have tried the sand blast on one of our bridges and it works very well and the expense is not excessive. It is done right along by the P. & L. E., in their shops at McKees Rocks, on their steel and iron work. It is particularly applicable to plate girders and such places where there is a large surface of metal. Where there is a large amount of open work and much lacing, so much sand is wasted that it makes it expensive; though there are a great many places, like corners, that are inaccessible to the scraper, that can be done thoroughly with the sand blast. It is not well to specify it for any place over a roadway where people are passing, as the sand is so much of a nuisance.

In painting surfaces exposed to passing locomotives they should be protected by burlap or wood until the paint is dry.

I have noticed a very peculiar phenomenon with a bridge in this city. In the near neighborhood was a chemical works where apparently they used considerable strong acids. On parts of the bridge near the ground, a year or two after it was painted, the paint would scale off, while up eight or ten feet from the ground, the paint was as good as could be expected. Some said it was poor work, but a painter will do his best painting down near the ground where people can see it and not up sixty or seventy feet in the air. The only way I could explain it is that the acid fumes from the works were heavier than the air, and attacked the bridge near the ground more than up above.

The drying of paint is not exactly a drying process, it is an oxidizing process. The hardening of the paint is a sort of slow combustion. It absorbs the oxygen from the air and the chemical action of the formation of carbonic acid takes place, and the object of using dryer is to furnish in the paint a substance that

readily gives off its oxygen, like black oxide of magnese or red lead. If you put in too much dryer the combustion goes too far and destroys the oil.

Mr. A. Stucki, Mem. Eng. So. W. Pa.—While sap wood properly painted may last longer than the heart, timber exposed to strains should be of heart. In car construction about 900 lbs. fiber stress is allowed for heart yellow pine and it is self evident that the soft sappy portion would not be nearly as strong.

Benzine is now often specified to be used in cleaning steel cars before painting and very good results are obtained thereby if properly wiped off, although the mill scale is naturally not removed.

Some years back we used air sprays very extensively on freight cars. It is a great time saver and many claim it is a paint saver. However it fills the air of the whole paint shop with atomized paint which is very disagreeable and also injurious to health. If applied too heavy I have also noticed that a tough skin forms on the surface, while underneath there was a floury substance which was possibly due to the fact that the pigment is heavier than the oil. On steel cars we do not use the air spray to any great extent except on trucks and brake rigging.

Is it not possible to write specifications for paint so that we may know beforehand what we are going to get?

Mr. H. E. Walters, Mem. Eng. So. W. Pa.—There was an article in the Journal of the Franklin Institute for July, 1904, by Mr. Job, Chemist of the Philadelphia and Reading R. R., in which he treated the problem of painting bridges from the point of the fineness of the pigment. He tested the fineness by placing it on glass at a temperature of 100°F. to see if it would separate from the oil.

Mr. D. A. Kohr—Mr. Job's theory was that the finer pigment better tended to fill up the pores of the oil.

Regarding specifications; it is hardly reasonable to ask the paint maker to tell the consumer just how to make the paint to get the best results because then any manufacturer could make it the same way, and each paint maker wants to make his paint a little better than that of any one else. And then it is pretty hard

to make specifications. For example; two barrels of white lead may analyze the same and yet when ground in oil, one may take 7% of liquid and the other 10%. And so with oxide of zinc. There is always variation. Such a thing as having pure pigment is out of the question, a commercial article is all we can get.

As to the quality of the oil; I did not say anything about refined oil because we use that altogether and every paint maker uses it unless he can't get it.

Mr. C. Evans, Jr., Mem. Eng. So. W. Pa.—I would like to ask what you mean by refined oil. Is it what is known as boiled oil?

Mr. D. A. Kohr—Simply oil that is aged, tanked six months, or two years would be better. Get it so the mucilaginous matter is settled out, along with water, dirt, etc. All that will settle out in time.

Mr. J. N. Chester—In regard to sap wood, it may be that it will hold the paint better and last longer, but with our experience in timber we would not want to recommend the universal adoption and use of sap wood instead of heart wood, even in yellow pine. Only a short time ago we examined a spill way that had been in use seven years. We found many of the timbers were yellow pine and the only universal rotting was between wind and water where the overflow had taken place, or where they had been mortised and tenoned and not creosoted. Apparently the timbers were all sound until we came to the last upright, a 14 x 14. A knife could be run into this with ease, and upon examination it was found that the soft or decayed portion was sap wood, and although it had been creosoted, after seven years it possessed no strength. On another spill way, where the timber had been treated with pitch or pine tar instead of creosote, we found practically the same thing.

A striking illustration of why we can't all afford the sand blast is given in the Cincinnati specifications for pipe for their filter plant, where there was a clause that the pipe prior to being dipped, or coated should be sand blasted, and that all projections or anything that tended to pierce the coating of the pipe should be thoroughly removed. The United States Cast Iron Pipe &

Foundry Co., added $2.00 a ton to their bid for sand blasting. When they got a quarter of the way through their contract they tried to lay down on the sand blast clause and they are asking much more than $2.00 per ton now. We know of nothing that needs thorough cleaning before coating more than does our cast iron pipe.

Everything that has been said about tanks can be applied to cast iron pipe. If any one will examine the interior of cast iron pipe that is tuberculated they will find that the start of the tubercle was a little projection that pierced the coating and spread like a boil or fester. Under such conditions the acid or alkali waters are going to take the coating out of our pipes. But where our pipes convey soft water they will be, at the end of forty years, as clean as when they were laid.

Mr. G. E. Flanagan, Mem. Eng. So. W. Pa.—We have seen a picture of an ancient sign that had been painted over the surface with white lead and the lettering done over that with lamp black. The illustration showed that all the paint had been worn away by exposure to the elements excepting the lamp black portion of it, even the wood itself had begun to wear away on all sides of the letters, leaving the letters in relief. Was that due to the preservative powers of lamp black?

Mr. D. A. Kohr—We have two such signs in our museum. But it has been a question in our minds whether if the priming coat had been lamp black and the letters white lead the result would not have been the same.

Mr. E. K. Morse, Mem. Eng. So. W. Pa.—Go over the second divide from here toward the Ohio River near Murdocksville, and if the same sign boards are there that were there three years ago we can show you by actual measurement where black letters stand out a quarter of an inch from the body of the wood that has decayed. That is the case not only there, but if you are along the lakes, Lake Erie especially, you will find sign board after sign board where the black letters are just as distinct as the day they were put on, the wood back of it rotting away.

That is one of the reasons why we believe in finishing up our present steel structures with black. If it will do that in a

sign board there is certainly reason why we should specify it for steel structures.

To-day we are allowing bridge structures to rust. There isn't money enough in the treasury to afford the luxury of a sand blast, but the scale must come off and the cheapest way is to let it rust off. It is not the question of peculiar excellency in a paint in our mind as much as the proper condition of the body of the structure receiving it, especially the removal of the mill scale.

STANDARD BOOKS ON PAINT AND PAINTING.

Painting and Painters' Materials, Charles L. Condet.

Fields Chromatography, J. Scott Taylor.

Encyclopedia Chemique, Vol. X.

Die Chemic der Austrocknenden Oele, G. J. Mulder.

Colors for Painting, Riffault.

Drying Oils, Boiled Oil, and Solid and Liquid Driers, Louis Edgar Andes.

Oils, Fats and Waxes, J. Lewkowitsch.

Painting and Decorating, W. J. Pearce.

Pigments, Paint and Painting, G. Terry.

Metallic Structures, Corrosion and Fouling and their Prevention, J. Newman.

Iron Corrosion, Louis E. Andes.

Painters' Colors, Oils and Varnishes, G. H. Hurst.

Chemistry of Paint and Painting, A. H. Church.

Chemistry of Pigments, E. J. Parry and J. H. Coste.

Science of Painting, J. C. Vibert.

The Laws of Contrast of Color, E. M. Chevreul.

Technology of Paint and Varnish, A. H. Sabin.

Rustless Coatings, M. P. Wood.

The Analysis of Oils, A. C. Wright.

Protection of Ferric Structures, M. P. Wood. Vol. 22 Trans. A. S. M. E.

SUPERHEATED STEAM.*

BY J. L. MOORE.
Member Engineers' Society of Western Pennsylvania.

If heat is added to dry and saturated steam, not in contact with the water from which it is formed, its temperature and volume is increased and it becomes superheated, or gaseous steam. According to Hirn, steam becomes steam gas, and so remains, when the superheat exceeds about sixteen degrees Fahrenheit.

When steam is superheated in a closed vessel where no expansion can take place, the pressure will increase with the temperature, as in the case of any ordinary gas. But, in practice, where steam is generated in a boiler, passes through the superheater and is then used in the engine, the pressure remains constant, while there is an increase in volume as the steam passes through the superheater, the increase in volume being assumed—in the present state of our knowledge of the subject—to be proportional to the increase of its absolute temperature.

Heat employed to superheat the steam increases the number of heat units per pound of steam carried by the engine, so that when a superheater is attached to a boiler, the heat available for evaporation of water is reduced by the amount employed in superheating the steam. For example, if ten per cent. of the heat is used for superheating, instead of evaporating water from the boiler, the effect will be ten per cent. less water evaporated per pound of coal burned, and the steam generated will carry away to the engine ten per cent. additional heat as superheat. Considering the boiler and superheater as one plant, the efficiency of the plant is unchanged, provided the temperature and quality of the chimney gases is the same in both cases; the heat supplied by the coal having been taken up in some form by the working fluid, whether to evaporate water or to superheat steam is immaterial from the point of view of efficiency of the steam generating apparatus. The effect, however, on the efficiency of the steam *as a working fluid* is very great.

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*Read at meeting of the Mechanical Section, March 7, 1905.

Of the sources of waste in a steam engine using saturated steam, that due to what is known as initial, or cylinder condensation, is by far the greatest. The object aimed at in the use of superheated steam in engines is to prevent condensation of the working fluid in the cylinder. If this result is attained, a large increase in efficiency results, as the loss from condensation is known to be from 25 to 40 per cent. in simple engines and 10 to 25 per cent. in the best compound engines of modern design.

The history of the steam engine from the time of James Watt to the present day, shows a continued attempt to reduce or eliminate entirely, by various means, the losses due to cylinder condensation. Watt's invention of the *separate condenser* was an improvement with this object in view. Previous to this invention the steam was condensed by the injection of a spray of cold water into the working cylinder of the engine, after the piston had completed its stroke. This cold water naturally cooled the walls of the cylinder to such an extent that a large quantity of the steam entering the cylinder on the following stroke was condensed. Watt foresaw the advantages that would result from keeping the temperature of the cylinder walls as nearly as possible equal to that of the working fluid in the cylinder, and designed the *separate condenser*, to which the steam was conducted, away from the cylinder of the engine, and condensed. The result was an enormous increase in efficiency.

There have been various methods employed by engineers to further reduce cylinder condensation, among which may be mentioned:

Compounding.
Reheating.
Jacketing.
Faster piston speeds.
Superheating.

Each of these methods has proved to be of more or less advantage in decreasing cylinder condensation, but superheating has been found to be the most effective of all, and is the only means by which it can be entirely prevented.

In the case of a simple engine using saturated steam, where

a large percentage of the steam is condensed in the cylinder, either during the admission period, or later during expansion, there is always water clinging to the walls of the cylinder which will be evaporated, or partly so, during exhaust, at the expense of the heat of the cylinder walls, leaving the walls of the cylinder at a much lower temperature at the end of the exhaust period than that which they would have were this water not present. Experiments have also shown that heat is much more readily transmitted from the working fluid to the cylinder walls when there is water in the cylinder, than when cylinder walls and working fluid are perfectly dry, as is the case when the steam is sufficiently superheated. With this type of engine a very high degree of superheat would be required to maintain the steam dry throughout the stroke, on account of the great range of temperature.

The compound engine offers peculiar facilities for superheating effectively, since the steam may be reheated between the high and low pressure cylinders, and thus kept dry throughout the entire range of expansion. With this type of engine using saturated steam, it has been found that it is not practicable to provide enough reheating surface in the reheater to superheat the steam to such a point as will give dry and saturated steam at the point of cut-off in the low pressure cylinder, owing to the large amount of moisture the steam contains when it enters the reheater. If, however, the steam has been superheated before entering the high pressure cylinder, the amount of moisture in it as it enters the reheater can be considerably reduced, so that a reheater having enough heating surface can be provided to effectively superheat the steam again before it enters the low pressure cylinder.

Some very good results have been obtained within the past few years with compound engines of this type using superheated steam.

Results of sixteen tests made by Prof. Schröter on a small tandem compound engine with reheater between high and low pressure cylinders are given in Table I.

TABLE I.

Results of tests made by Prof. Schröter of Munich on a 200 H. P. tandem compound engine using superheated steam:

Test Number.	I. H. P.	Degrees Superheat Fahrenheit.	Steam Used Per I. H. P. per Hour.
1	316	.....	13.43
2	277	.....	12.64
3	222	.....	12.08
4	170	.....	11.48
5	118	.....	11.84
6	22	.....	13.52
7	318	205.	10.71
8	272	225.	10.25
9	223	225.9	9.83
10	170	223.9	9.59
11	121	223.9	9.50
12	226	43.7	11.58
13	227	97.7	11 00
14	223	151.7	10.67
15	223	221.2	9.81
16	218	310.9	8.89

The dimensions of the cylinder of this engine were $12\frac{3}{4}''$ and $22''$ by $32\frac{1}{2}''$ stroke. The engine ran at 127 revolutions per minute. The steam pressure, 145 pounds gauge, and the vacuum, 27.8 inches, were practically constant throughout the tests. The steam valves were of the piston type. As will be seen, the engine gave excellent results either with or without the use of superheated steam, but 220° F. superheat at full load gives an improvement in economy of 18.8 per cent, while 310° superheat improves the economy 32.5 per cent. Tests 12 to 16 show the effect of a progressive increase of superheat with a constant load on the engine.

Table II.

Gives results of some comparative tests of engines running with, and without, superheat:

Type of Engine.	I. H. P.	Steam Pressure at Engine Gauge.	Vacuum.	Superheat at Engine F.	Steam used per I. H. P. per Hour.	Steam saved by Superheating	Test Made By
Double Acting Compound.	125. 184.	140. 140.	27.5 27.	0 197.	17.2 10.4	40%	Prof. Ewing, at Middlepolder, Holland.
Cross-Compound Rice and Sargent Engine.	407. 420.	145. 142.	25.24 26.79	0 374.5	13.84 9.56	30.9 %	Prof. Jacobus and A. C. Wood, at Millbourne Mills, Philadelphia, Pa.
Four Cylinder Triple Expansion Sulzer Engine.	3,000.	184. 188.	26.25 28.	0 223.	11.57 8.97	22.4 %	Prof. Schröter at Berlin.

If in the reciprocating engine the steam is wet at the end of expansion, a large quantity of heat is absorbed and carried away from the cylinder walls by the evaporation of this moisture during exhaust.

The steam turbine possesses an inherent advantage in this respect over the piston engine, inasmuch as the high pressure portion of its cylinder is not subject to the chilling effect of the exhaust, but has a temperature that is practically constant, excepting for slight changes in pressure and temperature due to a changing load—so that the steam entering the turbine cylinder comes in contact with surfaces having a temperature equal to its own.

The steam in the turbine, however, is wet from another cause. The loss of heat during adiabatic expansion due to work done in driving the rotating element causes condensation unless there be sufficient superheat in the steam when it enters the turbine to supply this loss. Superheating, therefore, is not of so great importance in the turbine as in the piston engine, since to prevent condensation in the turbine we have only to supply the heat lost

during expansion, while in the piston engine we also have to supply that lost by re-evaporation. As is well known, the turbine is better adapted to the use of high superheat than the older type of engine.

Results of carefully conducted tests seem to bear out these conclusions, for with the same conditions as to size of unit, steam pressure, vacuum, etc., the turbine will show a smaller improvement in economy with a given degree of superheat than the piston engine. As a general rule, experience has shown that the more wasteful and uneconomical the engine the greater will be the gain from superheating. Table III. shows the effect of superheat on the economy of turbines.

Table III.

Showing the effect of superheating on the economy of steam turbines:

Type of Turbine.	Size.	Vacuum.	Deg. Superheat Fahr.	Steam per hour per B.H.P.	Gain by superheating	Test made by
De Laval.....	200 K.W.	26.6	...	14.73		Dean and Main.
"	200 K.W.	27.2	81	13.55	8%	" "
Westinghouse-Parsons.....	400 K.W.	28.0	00	13.63	.....	" "
"	400 K.W.	28.0	182	11.25	17.4	" "
"	750 K.W.	28.0	...	13.95	.....	Shop Test.
"	750 K.W.	28.0	150	11.42	18.2	"

SUPERHEATERS.

There are various forms of superheating apparatus now is use. These consist usually of a series of cast iron or wrought iron pipes through which the steam passes on its way from boiler to engine, and are placed sometimes in the boiler setting, or in a separate setting and fired independently. Where cast iron pipes are used they are cast with internal and external ribs to increase the heating surface. A superheater placed in a boiler setting will

give a moderate or a high degree of superheat, depending upon its location, but the degree of superheat is not easily controlled with such an arrangement. With the separately controlled superheater the control is more easily accomplished, and almost any desired degree of superheat may be obtained. With the Schmidt system of superheating, where a separately fired superheater is used, the hot gases, after passing through the superheater, pass through an economiser and heat the boiler feed water. This allows the gases to be discharged at a very low temperature, and is a very efficient form of apparatus. A separately fired superheater without some such means of absorbing the heat remaining in the gases after they leave the steam coils would be rather inefficient, as the gases will leave the superheater proper at a very high temperature if a high degree of superheat is being obtained.

VALVES.

As to the form of steam admission valves best adapted to the use of high superheat, it may be said that corliss valves have not been found satisfactory, excepting for a very moderate degree of superheat, say up to 200 degrees Fahrenheit.

Piston and poppet valves have been found best for this service, and have been successfully used with temperatures as high as 600° or 700° F., which seems to be about the practical limit of superheating.

DISCUSSION.

Mr. S. B. Ely, Mem. Eng. So. W. Pa.—Is it not possible that superheating can be carried too far? If the boiler has a stack temperature of 600° or 700° F. it seems rather doubtful whether superheat enough will be given steam by an ordinary superheater after it has been in service for some time and is covered with soot and does not transmit heat from the waste gases very readily. The consequence is the boiler firemen are likely to run the stack temperature up, and the boiler efficiency will then, of course, decrease. The loss, by the decreased boiler efficiency, could easily outweigh what you gain by superheating. The gain

from superheating would probably not be more than 25% with the ordinary engine. Is it not possible that in the desire to get a good superheat there is a possibility of sacrificing the boiler efficiency?

Mr. J. L. Moore—I know of separately fired superheaters that give about 65% efficiency. They are so arranged that the gases, as they enter the superheater, come in contact with the part of it that contains the hottest steam, and leave it at the point where the cooler steam enters. By using the same idea in the superheater when placed in the boiler setting, I should think the results obtained would be equally satisfactory.

Mr. S. B. Ely—An economizer might just as well be introduced with the boiler as with the separately fired superheater. If the hottest steam comes in contact with the hottest gases then it is a question of getting heating surface enough in the superheater, with the corresponding high first cost. The fact remains that soot does get on the heating surface, and I should think would ultimately run up the stack temperature, in which case the efficiency of the boiler would certainly go down.

Mr. F. D. Purdy, Mem. Eng. So. W. Pa.—The claim is made, and I think it is well held up in boiler practice, that where they get high stack temperature they also get a direct economy from the high temperature coming in contact with the superheater tubes, more especially in water tube boilers. You can get as high as 150° superheat with a good water tube boiler.

In regard to the soot getting on the coils, they are generally placed where the air currents are quite strong and I think the tubes are well freed from soot, and if you don't keep your boiler clean it falls off in economy any way.

Mr. S. B. Ely—It is almost impossible to keep any tubes in a boiler free from soot, and the superheater will be no exception to this rule. There is one economizer provided with a scraper which is driven continually back and forth across the tubes to keep the soot off. I remember a case where in a new boiler installation the tubes directly over the fire kept burning out. The boiler people said that they had met with the same trouble before, and that it would stop in the course of a few

months. This proved to be the case, and the only reasonable explanation which we can advance is the fact that soot deposited on the tubes and protected them. Even when it is scraped off by hand it is practically impossible to get the tube absolutely clean without a great deal of work.

Mr. Edwin Fitts, Mem. Eng. So. W. Pa.—I believe the temperature of escaping gases, and efficiency of superheater, where the superheater is made a part of the boiler, depends entirely on where you place your superheater. If you want a high degree of superheat, you must put your superheater in the gases before they have passed over any considerable amount of water heating surface. If after leaving the superheater the gases pass over a sufficient amount of water heating surface to properly reduce their temperature there will be no loss of boiler efficiency. There are designs of boilers in which this can be accomplished. In other designs it can only be accomplished by adding an economizer, and there are still other designs in which a superheater cannot be applied to the boiler but must be separately fired.

Mr. Samuel Diescher, Mem. Eng. So. W. Pa.—Is the percentage of gain computed on the same amount of fuel? Say in one instance all the fuel is used to bring the steam up to the point of saturation at which it is used, and that gives a certain amount of work. In another instance a small amount of fuel is used for superheating with a special superheater. The same total quantity of fuel is used in each case. Is more work got out of the fuel in one case than in the other?

Mr. J. L. Moore—The efficiency of the engine would be so increased by the use of superheated steam, that with the addition of a small amount of fuel to superheat the steam you would get that much greater an amount of work out of the engine as to leave a net gain due to superheating.

Mr. F. D. Purdy—With the majority of engines the use of a superheater would be of no advantage. It must be an engine that is very carefully designed and has small clearance. By using superheated steam it is possible to use small clearances thereby reducing your initial cylinder condensation.

Prof. Storm Bull made quite an elaborate set of tests of an engine of about 30 H. P. using superheated steam and reduced them to a basis of the amount of coal consumed per horse power hour. The tests showed a large percentage of gain in efficiency, and also an economy in coal consumption.

Mr. H. H. Anderson, Mem. Eng. So. W. Pa.—I understand the Corliss engine is not as well adapted to superheat as an engine equipped with the poppet valve or piston valve. Is it a question of lubricating the Corliss valve?

Mr. F. C. Emery, Mem. Eng. So. W. Pa.—It is the warping of the Corliss valve that causes the trouble and is the only reason for its inefficiency in the use of superheated steam. There is so much difference in temperature between the ends of the valve itself and the surrounding metal that in such high temperature the valve will warp. You do not get the same effect in a piston valve, nor in a poppet valve.

Mr. H. D. James, Mem. Eng. So. W. Pa.—Is there any trouble lubricating the cylinders, and is any special type of valve used?

Mr. J. L. Moore—They use the ordinary type of piston valve, and I do not know that there is any difference in the poppet valves used for superheated steam from those in use with saturated steam.

With regard to lubrication, there is no difficulty on that point now because we have lubricants that have a flash point between 700° and 800° Fahrenheit. I believe in special cases where a very high degree of superheat is used they have an independent pump to force the lubricant into the cylinder and do not depend upon sight feed lubricators.

Mr. Edwin Fitts—There is a thing seen every day in boiler practice, and in the reports of boiler tests that, in my opinion, is very misleading. The dimensions of the boiler are given as so many square feet of water heating surface and so many square feet of superheating surface. This superheating surface is generally the surface in the drum, above the water line, over which the hot gases pass. As the steam is still in contact with the water, heat applied here will serve to bring it to

the saturation point and any heat applied in excess of the amount necessary to saturate the steam will immediately serve to evaporate more water. Steam to be superheated must be led through pipes, having hot gases on their outside, after it leaves the body of water. My contention is that heating surface above the water line in a steam boiler should be designated as such, and not as superheating surface.

Mr. S. B. Ely—In the discussion this evening one of the most important points in connection with superheating has not been mentioned. This is the danger from explosion, and applies particularly to engines that work intermittently, such as demanded in rolling mill service. If steam in going through the superheater reaches a temperature, of say, 450° F., the gases outside would possibly be 900° or 1,000°, and so long as steam keeps going through the superheater, heat is carried through the superheater walls and taken away by the steam. If, however, the engine stops, or other conditions arise, so that the steam is at a standstill in the superheater, then the steam will get hotter and hotter until it finally reaches the temperature of the gases outside. If the superheater is located in some part of the boiler or on waste heat furnaces or separately fired so that the gas temperatures run up 1,500° or more, the metal is likely to get soft and explosion occur. This makes it necessary to equip superheaters with thermostats and various automatic valves and devices so as to flood the superheater with saturating steam as soon as the steam has stopped going through it. On account of the complication, the uncertainty of satisfactory action and high first cost of these superheaters and devices, it seems doubtful if super-heating will ever be extensively used in rolling mill practice. Simplicity is the soul of machine design, and I do believe that we must get rid of this danger point in a superheater to make it generally used. Another point in this connection which applies to this section of the country is that the price of fuel has everything to do with the installation. I do not believe, where coal is cheap, that the economy gained offsets the interest on the money invested, the greater liability to stoppage and break-downs and the additional care and attention demanded.

Engineers' Society of Western Pennsylvania.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and fifty-fifth regular meeting of the Engineers' Society of Western Pennsylvania was called to order in the lecture room of the Society's House, 410 Penn Avenue, Pittsburg, Pa., Tuesday, May 16, 1905, at 8:15 P. M., with President Diescher in the chair and 50 members and visitors present. The following gentlemen registered:

MEMBERS.

Chester B. Albree,
H. H. Anderson,
H. C. Babbitt,
W. H. Baltzell,
Geo. T. Barnsley,
G. M. Campbell,
Francis W. H. Clay,
Ralph Crooker, Jr.,
R. D. DeWolf,
W. E. Dickson,
Samuel Diescher,
Edward J. Dittmar,
Edwin Fitts,
Gerald E. Flanagan,
J. M. G. Fullman,
E. F. Gwynn,
Herbert Hallsworth,
Richard Hirsch,
Alex. L. Hoerr,
H. D. James,
John L. Klindworth,
A. C. Knickerbocker,
J. Richard Kommer,
C. Ludlow Livingston,
T. D. Lynch,
George P. Maury,
F. V. McMullin,
Wm. Meyn,
J. J. Muir,
Francis S. Rice,
E. H. Riggs,
Edwin E. Rushton,
Jos. A. Shinn,
A. Stucki,
M. A. Tenney,
W. Trinks.

VISITORS.

John Barton,
A. B. Hurd,
Harry Ord,
Bruno Poensgen,
Hans L. Schred,
H. D. Klein.

The minutes of the last meeting were read and approved.

The report of the Board of Direction was read by the Secretary, recommending for membership 18 applicants.

On motion, the Secretary was instructed to cast the ballot of the Society for their election.

The Committee appointed to draw up resolutions on the death of Mr. Charles Parkin, reported as follows:

Charles Parkin.

Born in Sheffield, England, January 26, 1838; died May 27, 1904. Mr. Parkin came of a long line of steel makers, and was thoroughly trained in the whole art of Crucible steel making, melting, finishing, working into shapes, hardening, tempering, etc.

He came to Pittsburg in 1860 in the employ of Hussey, Wells & Co., in 1863 he went to the Black Diamond Steel Works, and in 1865 was one of the organizers of the firm of Miller, Barr & Parkin, Crescent Steel Works, where he spent the remainder of his active business life. It is no exaggeration to say that Mr. Parkin was the most competent steel maker and worker of his day in the United States.

It is owing to his great skill and good judgment that the Crescent brands became the standard of excellence all over the country, ranking quite equal to the best of the famous brands in the world.

Mr. Parkin, besides being so competent was a man of rare good judgment; he kept himself well informed of the great changes and advances in methods that made the last quarter of his century famous, and his product was always in the first rank in every advance.

Personally genial, of a kindly, helpful disposition it was always a pleasure to be associated with him, and he was untiring in his willingness to help. Even his most active competitors would come to him for advice, and he would give it as freely and promptly as if they were his best friends.

Added to this, he was a sincere Christian in his daily walk and life, upright, truthful, without guile, he was pure in heart,

clean in thought, clear in mind and altogether a charming lovable character.

WM. METCALF,
R. A. MCDONALD, } *Committee.*
PHILO KEMERY.

On motion, the report was accepted and ordered spread upon the minutes and a copy sent to the family of the deceased member.

MR. GEORGE T. BARNSLEY on behalf of the Reception Committee announced that they had arranged for an excursion to the new plant of the American Bridge Co., at Ambridge, Pa., on Saturday, May 27, 1905.

A paper on "Compound Reversing Engines" was read by Mr. Willibald Trinks, Member of Engineers' Society of Western Pennsylvania. After discussing the paper the meeting, on motion, adjourned at 9:50 P. M.

F. V. MCMULLIN,
Secretary.

NEW MEMBERS

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY.
JOHN BLODGETT,	American Bridge Co., h., 403 Bank St., Sewickley, Pa.	J. K. Lyons, Edwin A. Amaden, Frans Engstrom.
FELIX CREMER, Mgr.,	Pittsburg Metallurgical Co., Beaver Falls, Pa.	Samuel Diescher, A. Stucki, Fred C. Schatz.
FRANCIS DONALDSON,	Dravo Contracting Co., 814 Lewis Block, Pittsburg, Pa.	S. A. Scott, E. K. Morse, F. R. Dravo.
HENDERSON B. DOUGLAS,	Ass't to President, Standard Steel Car Co., Butler, Pa. h., 226 E. North St., Butler, Pa.	A. Stucki, Samuel Diescher, Willis Whited.
EMIL GERBER,	American Bridge Co., 1507 Frick Building, h., 834 Farragut St., Pittsburg, Pa.	Emil Swensson, Richard Khuen, E. A. Amaden.
ROY A. HUNT,	The Pittsburg Reduction Co., h., "B" Street, Oakmont, Pa.	Wm. Metcalf, G. H. Neilson, Samuel Diescher.
CHARLES BUTLER MCFAIL,	Gen'l Mgr., Holmes Electric Protectors of Pittsburg, 244 5th Ave., h., 3747 Bouquet St., Pittsburg.	Fred C. Schatz, Samuel Diescher, A. Stucki.

CHAS. B. MURRAY,	Chemist, Metallurgical Laboratory, 611 Bailey-Farrell Building, Pittsburg, Pa.	J. M. Camp. Francis C. Phillips. Geo. P. Maury.
W. R. PENDRY,	Draftsman, National Tube Co., h., 836 Huey St., McKeesport, Pa.	Ralph Crooker, Jr. Alex L. Hoerr. Gerald E. Flanagan.
ANTES LATROBE SNYDER,	Transitman P. R. R. h., 433 Ross Ave., Wilkinsburg, Pa.	Antes Snyder. Chas. Davis. Willis Whited.
CHARLES S. STEINMEYER,	Monongahela Connecting Railroad, 4736 Wallingford St., Pittsburg, Pa.	Frank McCune. E. K. Morse. Frank S. Slocum.
CLAY SPRECHER,	Mech. Eng., Allis-Chalmus Co., 1214 Frick Building, Pittsburg, Pa.	J. M. Camp. F. V. McMullin. Willis Whited.
LEE WHITTAKER,	Standard Steel Car Co., Butler, Pa. h., 2448 Braddock Ave., Braddock, Pa.	Gerald E. Flanagan. A. Stucki. Fred C. Schatz.
ROBERT LEE WILSON,	Westinghouse Electric and Manufacturing Co., h., 417 Denniston Ave., Pittsburg, Pa.	Chas. F. Scott. S. M Kintner. P. M. Lincoln.

MONTHLY MEETING OF BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at the Society's House, 410 Penn Avenue, Pittsburg, Pa., Saturday, May 13, 1905, at 8:15 P. M.

Present: Messrs. Diescher, Flanagan, Kintner, Lyons, Whited, Knowles, Barnsley, Schatz, Stucki, Anderson and Secretary.

Minutes of preceding meeting read and approved.

Resignation of Howard L. Brown accepted.

Treasurer's Report:

Dormant Fund	$3,617.59
Building Fund	1,302.32
Checking Account	4,576.44
Total	$9,496.35

Secretary's Report:

Membership May 13, 1905, 930.	
Collections April 15, to May 13, 1905	$ 840.36
Previously reported	5,334.88
Total, 1905	$6,175.24
Payments 1905 to May 13th	3,545.17
Bills were paid aggregating	313.85

On motion, the Secretary was ordered, in printing the minutes of the meetings in the Proceedings, to state only the number of names voted upon for membership, and only after the applicants had paid their initiation fee and first year's dues to publish their names in the Proceedings as new members.

The question having been raised as to the policy of the Society regarding reprinting papers in our Proceedings, on motion the Board reiterated the policy previously adopted, that the Society publish nothing in their Proceedings that had already appeared in any publication excepting it be a very exceptional case, and then only to be done with the sanction of the Board.

On motion Auditing Committee was authorized to devise a new system of accounts for the Society and put the same into effect.

On motion the Board adjourned at 10:00 P. M.

F. V. McMullin,
Secretary.

CHEMICAL SECTION.

The regular monthly meeting was held with the Pittsburg Section of the American Chemical Society, 410 Penn Avenue, May 18th. Chairman G. P. Maury presided, thirty-five members and visitors were present.

The meeting was called to order at 8:30 P. M. The minutes of the last meeting were read and approved.

Dr. F. C. Phillips called attention to the serious injury of a member, Mr. George O. Loeffler, in the recent Harrisburg wreck, and moved that the Secretary be instructed to express to him the sympathy of the members and their hopes for his speedy recovery. Carried.

The remainder of the evening was given to a discussion of the preliminary report of the Committee on the estimation of "antimony in the presence of tin," presented by Messrs. Phillips, Babb and Rich. This was discussed by Messrs. Babbitt, Walters, Mohr, Camp and others.

At 9:30 the meeting, on motion, adjourned.

HARRISON W. CRAVER,
Secretary, C. S.

MECHANICAL SECTION.

The regular monthly meeting was held Tuesday, May 2, 1905, at the Society's House, 410 Penn Avenue, Pittsburg, Pa. The meeting was called to order at 8:30 P. M., with Vice-Chairman W. H. Baltzell in the chair; 36 members being present.

The minutes of the last two meetings were read and approved.

On behalf of the Program Committee the Chairman, Mr. Fitts, reported the reason for the change in the program for the evening and the briefness of the notice.

On behalf of the Reception Committee Mr. Livingstone reported that a very pleasant dinner had been participated in by fourteen members.

Mr. G. M. Campbell then opened the discussion on Power House Management, illustrating his remarks by blue prints and charts. He was followed by Messrs. Crooker, Chas. Fitzgerald, J. N. Chester, Muir, R. H. Danforth and Greth.

Meeting adjourned at 10:15 P. M.

H. D. James,
Secretary, M. S.

STRUCTURAL SECTION.

The regular monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held in the Society House, 410 Penn Avenue, Tuesday evening, May 23, 1905.

The meeting was called to order by Chairman E. K. Morse at 8:30 P. M. 33 members and visitors present.

Minutes of last regular meeting read and approved.

The chairman announced that the Reception Committee of the Society had requested him to read the announcement of an excursion to Ambridge, Pa., on May 27th, and read the notice.

The chairman then introduced the speaker of the evening, Colonel T. P. Roberts, past President, who read a paper on "Cofferdam Construction." The discussion was taken part in by Messrs. Cummings, Donaldson, Morse, J. M. Rice and Hawley.

There being no further business, on motion the meeting adjourned at 9:50 P. M.

T. J. Wilkerson,
Secretary, S. S.

COMPOUND REVERSING ENGINES.*

BY WILLIBALD TRINKS,
Member Engineers' Society of Western Pennsylvania.

The reversing engines of our rolling mills are steam eaters. Rolling mill superintendents know this fact only too well from the large batteries of boilers which are required for reversing engines. A couple of typical indicator cards will reveal the waste-

FIG. 1

fulness of this class of engines. Fig. 1 is a full load card. Its appearance is similar to the cards of Corliss engines which do not release or carry the hooks. The visible steam consumption, not counting condensation, radiation and leakage, is 41.5 lbs. of water per horse hour and the actual steam consumption exceeds 45 lbs. per horse hour. The large back pressure during the first part of the return stroke is caused by the late release and the inertia of the column of steam in the exhaust pipe which cannot get away fast enough.

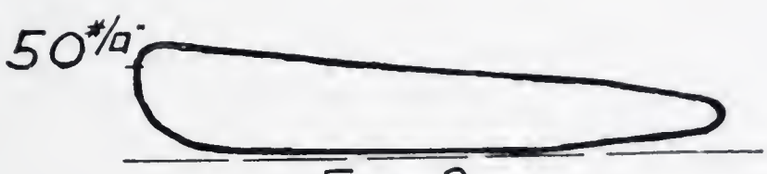


FIG. 2

Fig. 2 shows a typical light load card. The visible steam consumption is 34 lbs. per indicated horse hour and the probable steam consumption 39 lbs. per indicated horse hour, in which figure the superheating effect of the wire drawing has been taken into account. A comparison of this figure

*Read before the Society, May 16, 1905.

with the steam consumption of our modern power house engines is interesting. In power house engines and blowing engines we are accustomed to point with satisfaction to steam consumption of 12 to 17 lbs. per indicated horse hour; in reversing engines we put up with 40 to 50 lbs. per indicated horse hour.

The enormous steam consumption is apparently taken as a necessary evil. It is indeed an evil; coal costs money, even in Pittsburg; boilers cost money and take up floor-space; firemen's wages cost money, and so does the handling of ashes.

Attempts have been made to reduce the steam consumption without introducing complications or increasing the chances of break-downs. The means which have been adopted to this end will be described and analyzed in this paper.

The employment of expansion instead of wire drawing is very self-suggestive. However, there are difficulties in the road. A twin cylinder reversing engine must have at least 70% cut-off in order to start against the load from any position. The first one or two strokes of each pass must therefore always be wasteful and expansion can only be employed when long passes are rolled; even then its use is dangerous. For a given reduction in the mill and given hardness and temperature of steel, the work per revolution of engine is given. With the throttle wide open, constant speed of rolling can be maintained only when the cut-off is absolutely right for this given amount of work.

A slightly too long cut-off speeds the engine up continually; a slightly too short cut-off stalls it. The stalling action is very sudden on account of the small inertia of the rotating masses. It is almost impossible for the operator to gauge the cut-off correctly; consequently he runs on the throttle, which is very much easier, because the use of the throttle with $\frac{3}{4}$ cut-off absolutely precludes stalling of the engine. Even if the throttle is opened only $\frac{1}{8}$ of its normal lift, the engine pulls the piece through the rolls, very slowly, it is true, but without stalling, and this feature is valuable for the simplicity and reliability of the rolling operation. Besides, expansion causes uneven turning moments, which in turn result in uneven wear of the rolls. Most of the modern reversing engines are equipped with steam floating reversing gear, so as to allow any desired amount of expansion, but in

nine cases out of ten the floating gear is only used to throw the valve gear from $\frac{3}{4}$ cut-off forward to $\frac{3}{4}$ cut-off backward.

The desire to work with shorter cut-offs has led to the invention of the three cylinder reversing engine, which was introduced by Ehrhardt and Sehmer, of Schleifmuhle, Germany, and of which quite a number were built by that firm and by Gebrueder Klein, of Dahlbruch, Germany. It consists of three horizontal cylinders lying side by side and acting on cranks 120 degrees apart. For this type of engine, the maximum cut-off can be reduced to $\frac{1}{2}$ and the turning moment is somewhat more even with shorter cut-off than in the twin engine. However, the difficulty of gauging the cut-off correctly remains just the same as it is in the twin engines, so that the saving of fuel is comparatively small. In spite of other good features of this engine (such as interchangeability of the three duplicate units, the more perfect balancing of the reciprocating masses, etc.) the originators of this type do not recommend it any more for new installations.

Since long cut-off is essential in reversing engines, the only effective way of reducing the steam consumption consists in con-

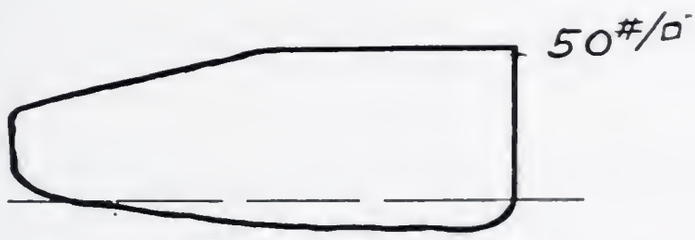


FIG. 3

FIG. 4

densation of the exhaust steam (as long as single stage expansion is adhered to). Figs. 3 and 4 show a full load card and a light load card, both taken off a reversing engine, running condensing.

The visible steam consumption varies from 31 to 33 lbs. and the probable steam consumption varies from 36 to 38 lbs. The saving over running non-condensing amounts to 15% on the average, of which about 4% should be deducted for the operation of the condenser machinery, so that there remains a net saving of 11%. Of course, the saving varies with the attainable vacuum, but it is great

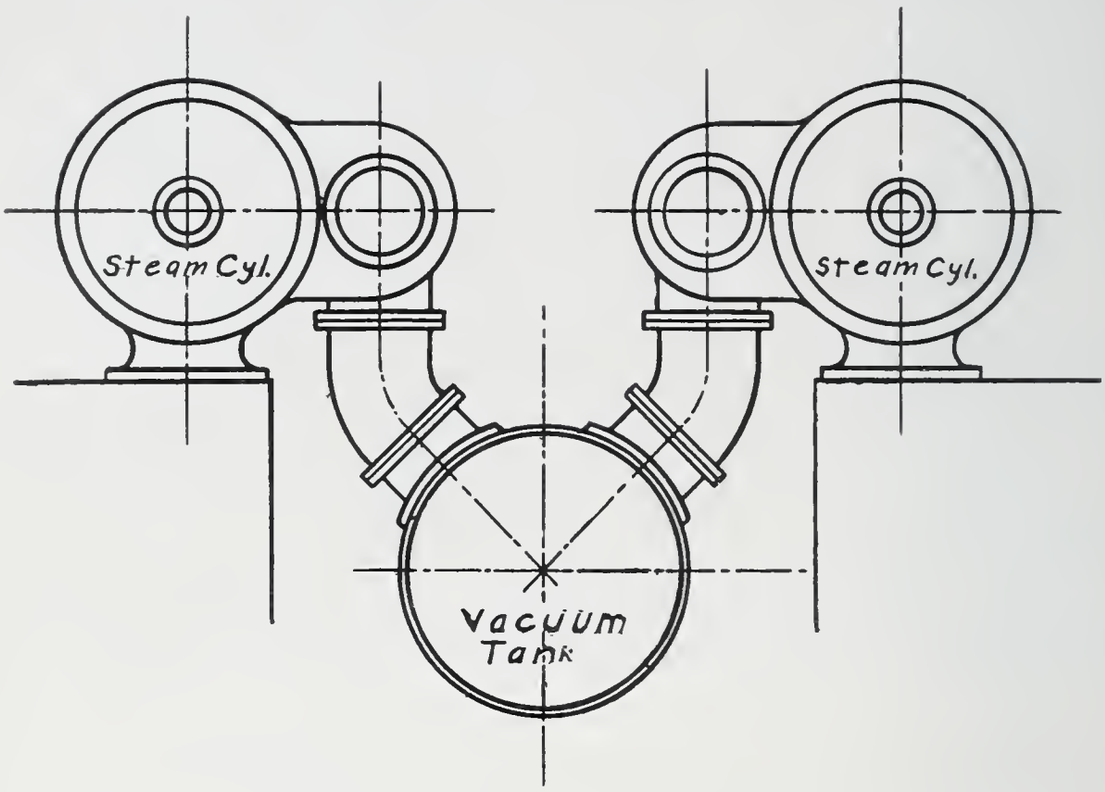


FIG. 5

enough to recommend condensation in all places where sufficient cooling water is obtainable. The exhaust from a reversing engine comes in gulps, and to secure a fair vacuum even at full loads, it is advisable to provide a large vacuum tank as close to

FIG. 6

the engine valve chest as feasible, see Fig. 5. Neglect of this precaution results in great back pressure just at the time when the actual steam consumption is greatest. The indicator card,

Fig. 6, taken off a condensing reversing engine without vacuum tank is a good example of how *not* to do it.

In spite of long cut-off, expansion can be obtained by compounding in a manner with which we are familiar from our compound and triple expansion duplex pumps. Fig. 6a is a combined

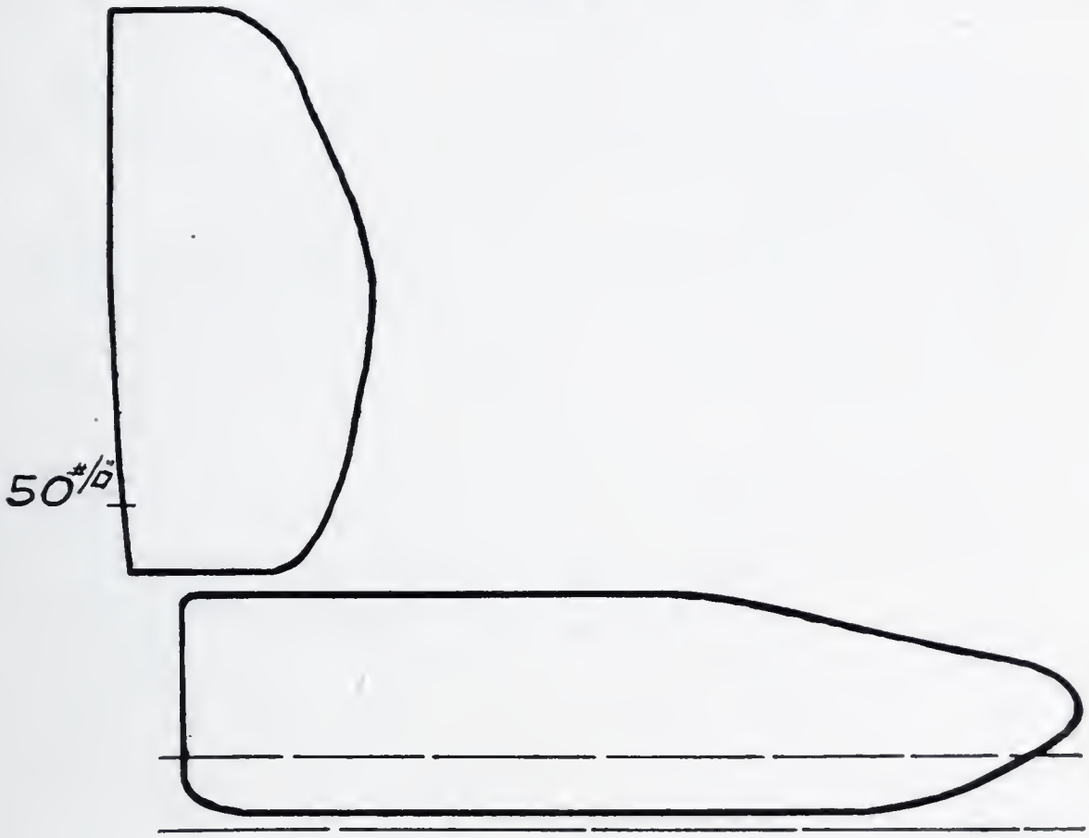


FIG. 6a

full load steam card, showing two stage expansion with 75% cut-off in each cylinder. With 22 inches vacuum at low pressure exhaust and 150 lbs. of steam pressure, the ideal steam consumption

FIG. 7

figures out 18½ lbs. and the probable steam consumption 22½ lbs. For lighter loads, the cut-off remains the same, but the high pressure steam is throttled; the receiver pressure drops and cards like Fig. 7 are obtained. With an ideal steam consumption of 23 lbs. and a probable steam consumption of 26 lbs., these figures are still above the 14 lbs. per horse hour of good power house engines, but they represent a decided progress when compared with the 45 lbs. per horse hour of the single non-condensing engine. The compound non-condensing engine will be dealt with later on.

While the consideration of fuel economy makes the use of compound condensing reversing engines desirable, there are other considerations which are decisive for final success, namely, sufficient starting power under all conditions, freedom from complications, and smoothness of operation. These considerations help to settle the question: Shall we build our compound reversing engines cross compound or twin tandem compound? The cross compound engine is apparently simpler and slightly more economical on account of smaller radiating and condensing surfaces, but it has some grave defects which limit its usefulness. It is evident that with the high pressure crank on or near the dead center, the low pressure crank has to do the biting of the piece and the starting. Sufficient receiver pressure for starting must therefore exist at all times. To this end means must be provided for shutting the receiver steam off from the low pressure cylinder, because the receiver steam would otherwise expand down to condenser pressure. The most efficient method of backing the steam up in the receiver consists in throwing the links to their central position. However, this procedure is not commendable, because it causes enormous compression in the high pressure cylinder, produces jerks in starting and causes loops in the high pressure card even at moderate loads. A throttle valve between high pressure and low pressure cylinder is more practical but not so efficient, because it can back up only a moderate receiver pressure without losing the benefits of compounding by excessive throttling. Special arrangements for admitting live steam to the receiver in emergency cases can therefore hardly be avoided.

It is evident that when the engine stops in the position of Fig. 8, that is when the high pressure valve has just cut off, the low pressure crank has a very small turning moment, whereas the back pressure on the high pressure piston exerts a great torque in the opposite direction. In order to start the engine

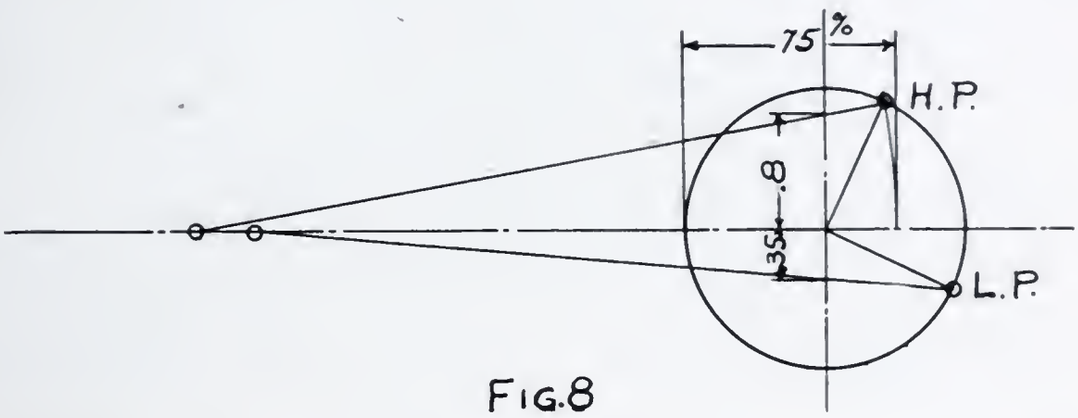


FIG.8

from this particular position, either an intercepting valve between high and low pressure cylinders or else a very long cut-off of the high pressure gear, say 85%, becomes necessary.

The worst feature of the cross compound reversing engine consists in the uncertainty of an even distribution of work over the two cylinders. It is next to impossible to distribute the work evenly under all conditions, with the result that the rotative speed varies greatly and the rolls wear rapidly. These remarks are not to be applied to reversible cross-compound engines, that is fly-wheel engines, which normally run in one direction only, and in which the reversing feature is used in emergency cases only.

Most of the defects of the cross compound engine are avoided by the twin tandem compound engine. No matter how the engine stops, there is always one high pressure side open to live steam. The high pressure cylinders can be made large enough for starting without any fear of causing uneven distribution of load over the two sides of the engine. The power of both sides is the same no matter whether the high pressure cylinders or the low pressure cylinders do most of the work. No intercepting valves or unduly prolonged cut-offs are required to secure absolute reliability of starting. The high pressure and low pressure cylinders are close together, so that the receiver volume is small and the discharge from the high pressure cylinder works im-

mediately in the low pressure cylinder without having to fill up large empty volumes.

With the certainty of saving in fuel consumption, and of reliability in quick starting and stopping, it is to be wondered at that the twin tandem compound reversing engine has made very little headway in this country when compared to Belgium, France and Germany. In these countries a great number of tandem compound reversing engines have been built and are in successful operation. Of course, fuel consumption is more of an item over there than it is here, and the word "tonnage" has not nearly the same inducement to the European as it has to the American. This may be the key to the situation. Our rolling mill men are afraid that the additional cylinders and valve gearing may involve additional break-downs and shut-downs, so that (to use a common phrase) "the gain would be a loss."

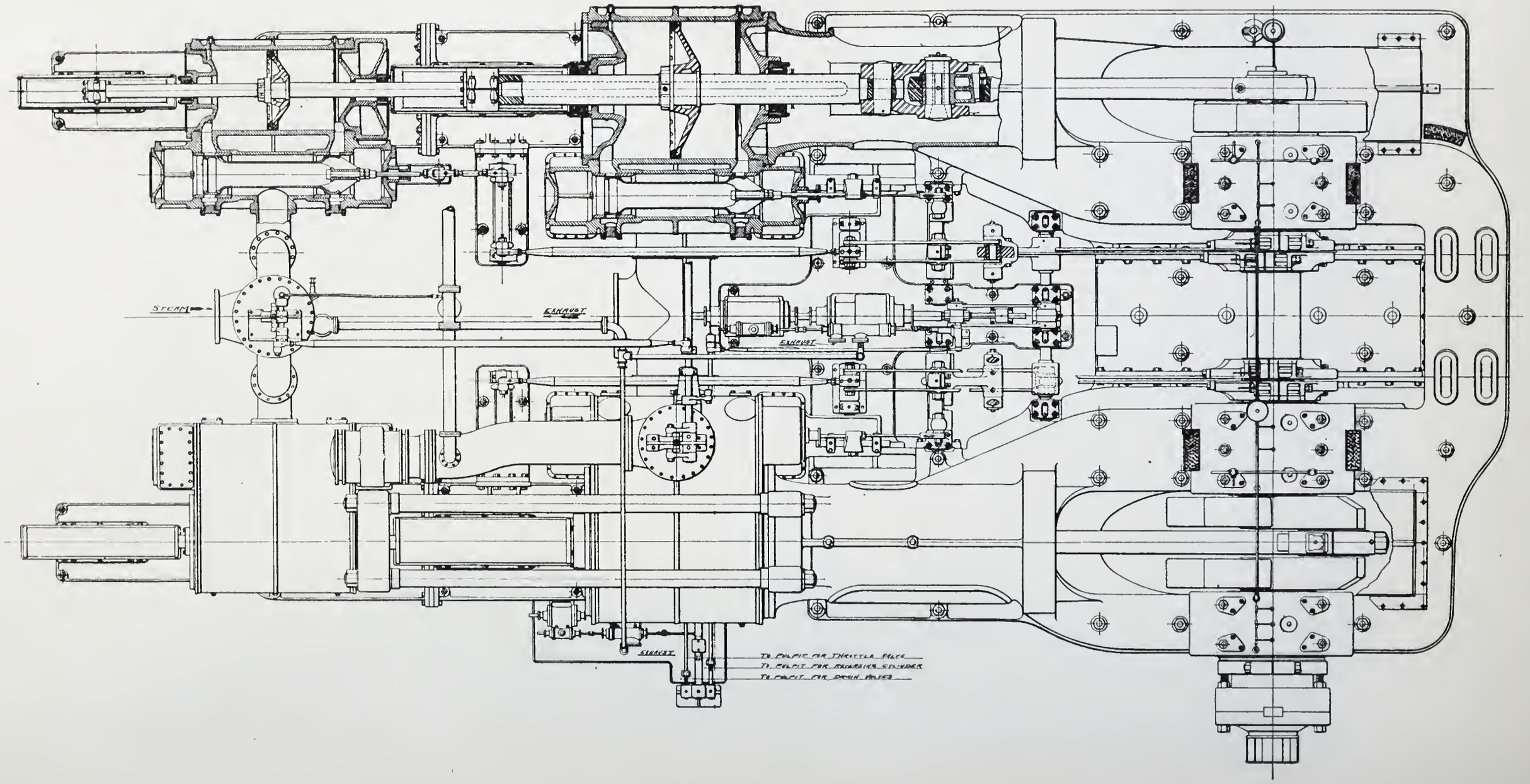
It is undoubtedly true that the tandem compound engine contains more moving parts than the simple engine, but it is also true that these parts can be built in such a way that the danger of break-downs is reduced to a minimum. Above all, the reciprocating parts must be as light as is consistent with proper strength; they must be balanced in the cranks and not by a balance-wheel between the main bearings, because this latter construction induces excessive strains at high speeds. At the same time the pistons should be floating free in the cylinders and be carried on adjustable slides. The valves must be built light and strong, and in case they are piston valves, should be built of the tubular form, to avoid the shock which is peculiar to piston valve gears at full load, and which is caused by the unbalanced pressure of the exhaust steam. If these precautions are followed the valve gearing, its pins and eccentrics, need not be excessively large.

Experience has proven that a shutting-off organ between high pressure cylinders and low pressure cylinders is desirable, although not absolutely necessary, because a skillful attendant can back up sufficient receiver pressure by judicious use of the reversing links. As stated in an earlier part of the paper, the use of the central position of the links causes excessive compression, and for this reason modern twin tandem compound reversing engines are equipped either with low pressure throttles or else

with a valve gear arrangement which shortens the low pressure cut-off without increasing compression as soon as the high pressure throttle is closed down a certain amount. This latter gear is known as the Rottmann valve gear and is built by Ehrhardt & Sehmer. It is more ideal than the low pressure throttle, but hardly suited for American practice, on account of the great number of small parts and loose joints. It is essentially a combination of a link reversing gear with a floating Myer Cut-off and a Thompson compound rocker.

The arrangement of throttle valves on the low pressure cylinder is not as ideal as the Rottmann valve gear, but it is infinitely superior in practical operation, because it does away with a car-load of small parts and pins, and also with the heavy low pressure main valve. The proper amount of throttling between the two cylinders is determined as a compromise between conflicting conditions. Throttling between high and low pressure cylinder impairs steam economy and should from this standpoint be avoided altogether. On the other hand, the maintenance of a high receiver pressure for starting would call for more or less throttling at all loads. Both of these demands can be approximately fulfilled by arranging the low pressure throttles in such a way that they enter into action only on the light loads: this means that the low pressure throttle must open quickly and be wide open when the high pressure throttle has lifted very little. In this manner it is possible to maintain about 20 lbs. absolute receiver pressure for starting, also to avoid the cooling out of the high pressure cylinder walls, and yet not to have any throttling with medium or heavy loads.

Fig. 9 shows plan and elevation of a 36 & 62 x 54 twin tandem compound reversing engine, of which two are now being built by the Wm. Todd Co., for the Illinois Steel Co. Care has been taken to bring these engines up to the American standard of reliability and accessibility. Both high pressure and low pressure pistons are carried on adjustable slides, resting on a heavy soleplate. All pistons are easily accessible and removable. The piping between high pressure and low pressure cylinders is made as short and direct as possible; the low pressure throttle has been placed as near to the low pressure cylinder as possible,


STEAM
EXHAUST
EXHAUST
EXHAUST
TO PULPIT FOR THROTTLE VALVE
TO PULPIT FOR REVERSING CYLINDER
TO PULPIT FOR DRAIN VALVES

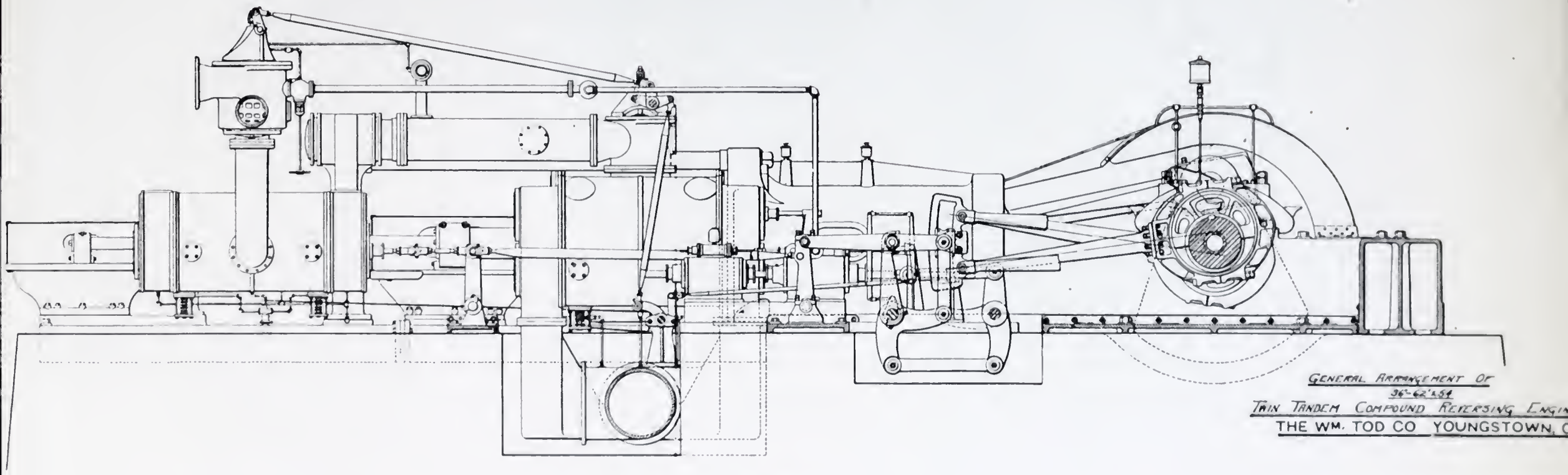

GENERAL ARRANGEMENT OF
36"-62"x54
TRIN TANDEM COMPOUND REVERSING ENGIN
THE WM. TOD CO YOUNGSTOWN, O

FIG. 9

actually hanging in the low pressure steam chest; each low pressure cylinder is controlled by two tubular piston valves, which are duplicates of the high pressure valves. The reversing links and the throttles are operated by steam floating gears with oil cataract cylinders. An automatic by-pass has been provided to maintain a high receiver pressure for starting as soon as the throttle valves are closed. Cylinders and steam chests are provided with drain valves which can be operated from the pulpit; the whole engine is piped up for central oiling system and provision is made to catch every drop of oil, except cylinder oil.

A glance at the main parts, 24 x 42 main bearing, 24 x 30 outer bearing, 24 x 13, large crank pin, 14 x 13, small crank pin, 11 x 14 crosshead pin, shows that their sizes are larger than those of single expansion reversing engines of equal power.

A few words need be said concerning the non-condensing operation of compound reversing engines. While there is a saving of 15% in steam consumption over the simple non-condensing engine at medium and heavy load, there is a loss of from 10 to 15% at light loads, such as they are encountered in rolling down to 4 x 4 from about 20 x 20 with one engine. The non-condensing compound engine should therefore be used only in special cases, that is, where water is scarce and where the temperature of the atmosphere is so high that an excessive amount of water is evaporated in order to sufficiently recool the water for further use. Such conditions exist, for instance, in several places in Mexico but here in the States condensation should be employed even where water is scarce, because water can be sufficiently and cheaply recooled in or over a pond with spray nozzles; the amount of water which evaporates and which must be pumped is, as a rule, smaller than the boiler feed water which must be pumped for non-condensing engines. As to the first cost of the condenser, it is no object, as the following figures will show. An average price for boilers is 50 cents for one pound of steam per hour; a similar price for elevated condensers is 10 cents for one pound of steam to be condensed per hour; the compound condensing reversing engine saves, say 35% over the single non-condensing, so that the cost of its boilers and con-

denser compares to the boilers of the non-condensing as $\frac{0.65 \times 50 + 10}{50} = 0.85$; that is to say, the cost of boilers and condenser for a compound reversing engine is 15% less than the cost of the boilers for a single non-condensing engine, which helps considerably to pay the 35% to 40% increase of cost of the twin tandem compound over the twin single engine.

With hardly any increase of first cost, the compound reversing engine recommends itself for all installations, even in the Pittsburg district. When it comes to remodeling existing simple non-condensing reversing engines, the case is somewhat different. Where high freight has to be paid on coal, the compound engine should surely replace the simple engine, but where coal is as cheap as it is in Pittsburg, the game is hardly worth the candle. To tandemize a simple engine, the existing cylinders of diameter D must be bushed to bring their diameters down to 0.8 D and low pressure cylinders of 1.27 D must be added. As a rule, the whole old valve gear has to be thrown away, because it is not heavy enough for carrying the valves of the added cylinders, the counterbalance in the cranks is no longer right, etc. A close calculation of the cost of rebuilding and of the saving of fuel results in comparatively small gain for this district. However, this cannot change the statement that for all new installations or replacals of engines the compound reversing engine should be given preference over the simple non-condensing engine.

DISCUSSION.

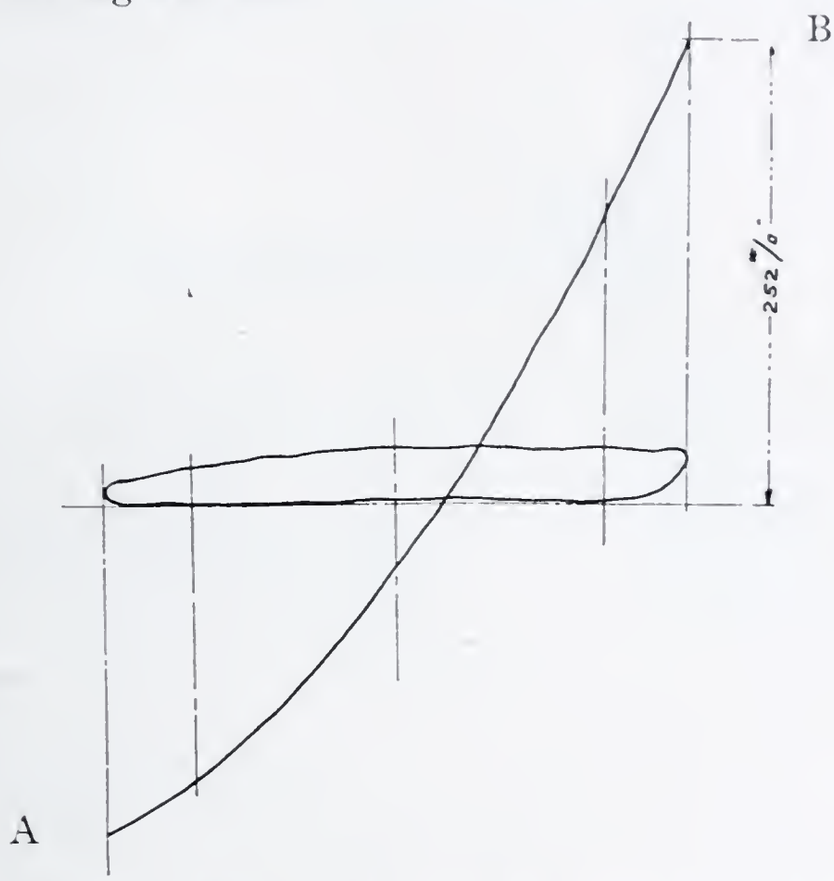
MR. SAMUEL DIESCHER, Mem. Eng. So. W. Pa.—Mr. Trinks, will you explain further as to the gain in using cooling devices, and the statement that the amount of water required is less with a condensing plant that has a cooling arrangement than it is where there is no condensation at all?

MR. WILLIBALD TRINKS—In a non-condensing engine we have to pump the boiler feed water which goes into the air as steam. In a condensing engine which uses either a cooling tower or spray nozzles, a certain amount of water evaporates and this quantity must be pumped. The same water is used over and over with the exception of the amount which evaporates, and this is as a rule smaller than the quantity of feed water which is commonly pumped for non-condensing engines.

MR. RICHARD HIRSCH, Mem. Eng. So. W. Pa.—On your indicator card, what percentage of the total inertia of reciprocating parts do you usually take up by compression?

MR. WILLIBALD TRINKS—This compression question is a very serious one. Ever since Radinger published his famous book on steam engines with high piston speed, we have heard too much about taking up the inertia of reciprocating parts. The impression seems to prevail in the minds of a great many engineers that the inertia of the reciprocating masses should be almost entirely taken up by compression so that at the end of the stroke the crank pin would hardly have to sustain any load. There may be something in this theory for engines which run at a constant speed, but there is certainly nothing in it for reversing engines which may run at the rate of 50 R. P. M. now and five seconds later at the rate of 150 R. P. M. A few weeks ago I saw one of our latest reversing engines running at from 175 to 180 R. P. M. by tachometer with 60 inches stroke, making a piston speed of about 1,700 to 1,800 feet per minute. This speed does not last longer than six to seven seconds at a time. They break down to 4 x 4 and those 4 x 4 pieces are, I think, 90 feet long, so that it does

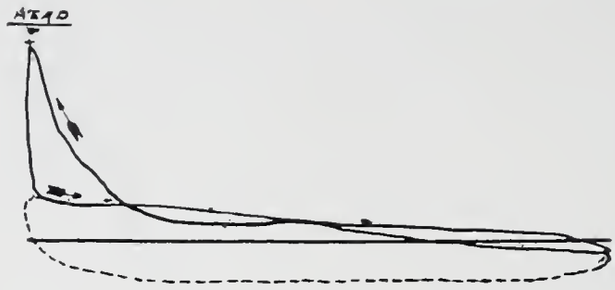
not take very long to get them through. The indicator card looks something like this



with very little compression and when you come to lay off the inertia curve it looks like A. B. That is to say, the inertia in this engine is often equivalent to 250 pounds per square inch in the steam cylinder. Even if you make the reciprocating masses as light as you know how, the inertia at 150 to 160 R. P. M. goes up to the equivalent of 200 lbs. per square inch. It is impossible to take up that force by compression. Still the engines run quiet.

The question of quiet running is not a question of magnitude of inertia, or compression forces, but it is a question of the suddenness in the change from exhaust pressure to admission pressure. I have known cases where the very desire of the designer to make the engine run quiet by taking up inertia by compression defeated his object. For instance we have had engines in which the valves were set for running condensing and the compression was made so that the inertia of the reciprocating parts would almost be taken up by compression when running condensing. It happened in many

instances that the condenser was not ready when the engine started and instead of getting the dotted card



we got the card shown in full lines. We certainly had all the compression we wanted and more but the engine pounded as though it would go to pieces. Why? We had all the inertia taken up by compression so that according to that theory there was no reason for pounding. The cause of the pounding is the sudden drop from compression-end-pressure to admission, which causes a corresponding change from tension to compression in the rods.

The theory that the inertia of the reciprocating masses must be taken up by compression has led to quite a number of similar mistakes. You can take up inertia by compression and can stop the parts without loading the crank pin but with such a card you cannot start them without the aid of the crank pin, because there is not sufficient pressure in the cylinder for that purpose.

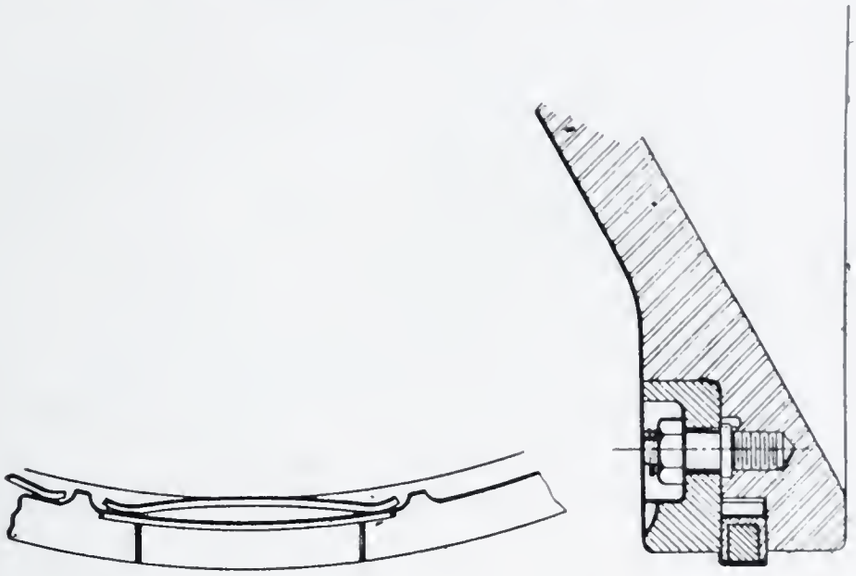
Mr. Richard Hirsch—What kind of packing rings do you use?

Mr. Willibald Trinks—Floating pistons with single packing rings of very simple construction. They are rings split in two with lugs and flat springs behind them. The cast steel pistons do not touch the cylinder, the rings project 3/16 beyond the piston and are held down by a follower.

Mr. Richard Hirsch—How do you lock the follower stud nuts?

Mr. Willibald Trinks—Each stud has a collar and is screwed up tight against the collar. In this collar is a dowel pin so that the stud cannot turn. Above the follower nut is a split pin. The nut cannot turn on account of the split pin,

the stud cannot turn on account of the dowel, and the dowel cannot come out because it is held down by the follower.



Mr. C. B. Albree, Mem. Eng. So. W. Pa.—Do you pack the piston valves in any way?

Mr. Willibald Trinks—Yes, with concentric snap rings.

Mr. C. B. Albree—Is the ring free to slide past the port?

Mr. Willibald Trinks—No, the split of the ring always rides on a straight rib that runs parallel to the axis. It would be dangerous to have it turn.

Mr. Arnold Stucki, Mem. Eng. So. W. Pa.—It is somewhat surprising that compound engines are economical in a field like this. In locomotive practice the compound engine is considered useful in long runs but not on short ones where many stops occur. In this case we have nothing but stops and starts. It is true condensing engines are out of the question on locomotives, but to some extent it is a parallel case.

Mr. Willibald Trinks—It is interesting to know whether the calculated saving is actually obtained and the opportunity for making actual comparison tests is very seldom offered. Mostly the economy of a reversing engine is figured from indicator cards and while we know from our boilers that we use less steam we cannot say how much less on account of other engines which are fed from the same boilers. It will therefore interest you to know that an actual test has recently been published in Stahl and Eisen, April 1, 1905.

In a rolling mill in Luxemburg a twin non-condensing engine was changed to a twin tandem compound condensing engine with low pressure throttle valve.

The same boilers were used before and after the change. The boilers also fed the auxiliary machinery for the roll tables so that only the difference before and after the change could be measured, but not the total amount. The reduction in cross-section of steel was 13.4 before the change and 14.26 after the change. The saving per ton of steel amounted to 610 pounds of steam. It was found that the boilers evaporated 7.75 lb. of steam per lb. of coal, so that the saving in coal amounted to 78 pounds per ton of steel.

Mr. Ralph Crooker, Jr., Mem. Eng. So. W. Pa.—How many times per minute can you reverse such engines?

Mr. Willibald Trinks—Just as often as you wish; because of the throttle on the low pressure cylinder the action is just the same as though you had a simple engine. You could not do it with the high pressure throttle alone.

Mr. Ralph Crooker, Jr.—Take an ordinary reversing engine and put it on the condenser and it will be very sluggish in stopping. When you put the low pressure cylinder on you have something which starts that engine slowly, so I should say the engine would be sluggish in doing its work. Do you know what the actual performance is?

Mr. Willibald Trinks—I know of no comparative experiments concerning the time of starting and stopping reversing engines with a low pressure throttle; but I know of such experiments on engines with Rottmann valve gear, which is very similar in its action to a low pressure throttle, because it acts as a low pressure throttle and cut off combined. For an engine of that class 935 and 1,400 x 1,300 m.m. geared 1:2.75 the steam consumption for the old simple engine was 186 kilograms per ton of steel, for the new compound engine it was 92.2 kilograms. The compound condensing engine rolled the material in 2/3 of the time which the simple non-condensing engine required.* I fail to see why the compound

*Mr. Trinks remarks that he forgot to state that the new engine was of very nearly the same power as the old one. See *Stahl und Eisen*, 1903. —Ed.

engine should be slower providing it has the proper means for starting and stopping. A simple non-condensing engine has a great volume of steam between the throttle and the piston. If you add a condenser it is slower in stopping because the steam between the throttle and the piston expands. If you could have the throttle right at the piston, then there would be no difference between condensing and non-condensing, because the slightest motion of the piston would create a vacuum immediately; and if you have low pressure throttles which are very close to the low pressure cylinders, so that there are no dead spaces between the throttle and the cylinder then there is no reason why that engine should be any more sluggish in starting and stopping than the common type. The whole trick is to get the low pressure shutting off valve as close to the piston as possible.

Mr. J. L. Klindworth, Mem. Eng. So. W. Pa.—Are any compound reversing engines in use in the United States?

Mr. Willibald Trinks—As far as I know there is at the present time only one large engine in use in this country, and that is at the Cambria Steel Co.

It was built by the Southwark Foundry and Machine Co. at the time when I was a draftsman with that concern. I did a great deal of calculation work on that engine, but did not design it. To my knowledge it is the only compound reversing engine now in use in the States. It is a twin tandem compound engine and has been in use between four and five years. I had originally intended to describe the engine in detail, but I failed to obtain the sanction of the builders and I would not consider it fair to them to describe it here without their sanction.

However, I consider myself at liberty to publish a letter from Mr. Morgan, chief engineer of the Cambria Steel Co., in which he says: "We consider the engine entirely successful and economical in driving a large slab mill. It reverses promptly and easily without live steam and does not stall. It is working condensing. The engine has been repeatedly and carefully indicated by our own and Southwark engineers by

continuous indicators showing the cards under all conditions and the average steam consumption per I. H. P. is about half that of the ordinary high pressure non-condensing, reversing engine driving a blooming mill near by."

There used to be one at the Illinois Steel Co., but it died from "marasmus senilis." It failed not on account of the compound principle but on account of general weakness. It was too light in all parts.

VALUE OF PURE FOOD LEGISLATION.*

BY ABRAHAM GROSS.
Non-Member.

The marvelous progress made by the commercial world in the past few years, marks a tribute to human endeavor. But in the ultimate analysis there unfolds a series of evils which mar in many instances the success of these efforts.

The policy of business expansion pursued with a view of production at a mimimum cost has lead to a decided change in the nature of the products themselves.

Necessarily a reduction in the cost of a product implies cheaper raw material, lower cost of production or less profits. The latter is, however, rarely disturbed, but the question of cheaper raw material is always a factor of great importance.

Unfortunately the desire very often is, not for the same material at a less cost, but for cheaper material, and if the price is not sufficient to meet competition, or yield sufficient profits, a substitute of even less cost is secured, and used.

The success of production under this condition depends very largely on the skill of the producer; but when this skill is not available the products are sent into the market unfit for use, and without regard to consequences.

This practice, serious enough in any department of commercial activity, becomes a menace to human life when brought into the domain of food and drug production. The years of unrestrained liberty in this field, and the attendant evils resulting from the abuse of this privilege, have forced the public to cry out against the imposition, and demand a cessation of this dishonest method. The result has been the institution of pure food regulation, and although such questions as these, which directly affect the public welfare, meet slow

*Meeting of Chemical Section, April 20, 1905.

success, still the state has shown sufficient interest to encourage some degree of satisfaction.

No reputable manufacturer fears any demand of proper food legislation. He realizes that the inferior products which have enjoyed some degree of success must ultimately improve their quality, or be excluded from the market. In his observance to what the law demands, the legitimate producer is often in a dilemma. He places his goods on the market in almost perfect condition. The success of the product (unless widely advertised) very often depends on its keeping qualities. Without any preservative in the product, the consumer is forced to discard the article after little use, and ultimately the maker suffers the consequences of reduced sales.

This question is one of serious moment, and while many throw up their hands in horror at the mention of preservative, it still remains one of the difficulties yet to be regulated. The indiscriminate use of preservative needs no special comment, but a proper method to overcome this obstacle will be a welcome innovation. Possibly Dr. Wylie's investigation will throw some light on this question.

The most important phase of the pure food question is that which concerns itself with substitution or adulteration. It is wonderful how prolific the human mind becomes when used in this direction. Imitations are so skillfully made that the consumer is readily deceived. We admire ingenuity, but would rather have it remain out of our food.

This practice will be easily overcome by proper legislation. Its success depends on the ignorance of the purchaser, or consumer, and can be stamped out to a marked degree when the proper facts concerning such products are made known.

Some dealers will take the risk of selling adulterated goods if the manufacturer agrees to pay the costs of a law suit. This dealer forgets that his business reputation is at stake in this venture, and from present indications this practice is declining.

An examination of the names of offenders will disclose some of the smallest merchants. It is obvious to every one

that many of these have innocently bought goods contrary to the requirements. What seems like an injustice in this case, in reality is strict justice, as it teaches themselves and others to exercise care in the purchase of their products.

The root of the evil rests primarily with the manufacturer, but as he is rarely in the position of selling to the consumer, the law cannot strike directly at him.

Several states require of fertilizer manufacturers a standard sample of their various products. These must reach the purchaser according to the quality prescribed by law, the failure of which subjects the manufacturer to a penalty.

It would be a marked advance in food legislation to establish some system of this kind for food products. At any rate some standards are necessary, and would assist in keeping the production of inferior products at a minimum.

In spite of the fact that substitutes are designed mainly to cheapen the cost of a product, in many cases they are better than the originals. This is especially true of flavoring products and colors. A regular extract of the vanilla bean is almost worthless in baking, while artificial vanillin, (the aromatic principle of the vanilla bean), answers this purpose admirably. The vegetable colors do not equal in any way those made from aniline, and still others might be mentioned in this connection, which prove a benefit rather than an injury to the product.

However it is here again that the indiscriminate or fraudulent application of these substitutes condemn their use.

A purchaser expects the article he buys to serve a certain purpose, and if the natural product fails to meet the requirements, he naturally suffers some lose by the deficiency.

The requirement to make the label show the nature of the article does not always acquaint the purchaser of the true contents. These labels are very often like picture puzzles, which require very careful study to uncover their hidden meaning. Besides they are often untrue, and worded so that the purchaser is unable to interpret the exact nature of the ingredients.

It is obvious that legislation so far reaching in its effects and benefits as that regulating food products, requires considerable modification before it can adjust itself to practical purposes. But however defective or inadequate the regulations might be, they carry with them an element of the right, which alarms the unscrupulous and points out his departure at no far distant day.

The success of pure food regulation will bring with it a higher standard of products, and the basis of competition would then necessarily rest upon a question of quality rather than upon the best that can be made at a minimum price, irrespective of quality.

The producer who is hopelessly at a loss to cope with present conditions would be accorded a fair opportunity to find a market for his products, and above all, the consumer who pays for the purest and best would get a product that represented the highest type of its class.

TOPICAL DISCUSSION ON POWER HOUSE MANAGEMENT.*

Mr. G. M. Campbell, Mem. Eng. So. W. Pa.—Power house "management" is getting the best results in the way of power output at the lowest cost. To accomplish this it is necessary that a systematic record be kept of all expenses and of the output of power, for it is mainly by careful comparison of such figures that costs can be reduced and output increased for the same outlay. In scanning the record of expenses, it would not be sufficient to consider prices in the abstract, material must also be taken account of, for example, a high grade cylinder oil at 65 cents a gallon would undoubtedly be cheaper for many purposes than a poor grade at 35 cents. Again, it is often poor economy to be too careful about the amount of supplies used; the wear and tear on the machinery by use of insufficient supplies may far exceed the saving in supplies.

For the best results the plant should be designed with the object of economy and efficiency in view; boilers, engines, pumps, etc., should be chosen with particular reference to the conditions under which they will work, and everything should be so installed that it is capable of being easily repaired, i. e., there should be working space around all apparatus, and pipe lines, valves, etc., should be easy of access. All large power houses are equipped with cranes, the smaller plants are not always so equipped but they should be, and if a crane is not part of the original installation it should be added.

It is generally assumed that a low water rate condensing plant is more economical than a non-condensing one where the rate is higher, but such is not always the case. If all the heat in the exhaust steam can be made use of then relatively inefficient but low cost engines would, when interest and depreciation as well as the coal pile are considered, be the cheapest to install and maintain. If steam from the boilers is

*Meeting Mechanical Section, May 2, 1905.

eventually discarded as water and at the same time the feed water enters the boiler at or near 212°, what more could be desired or obtained? I have in mind a non-condensing plant of 2,000 B. H. P., which in winter uses every ounce of exhaust steam and in summer a very large percentage of it. That plant is working very economically, though the engines and pumps installed have a high water rate.

In general, do not worry and scheme to simply repair troubles, but remove the cause. If you are burning out tubes in your boilers and keeping gangs of men putting in tubes or cleaning the scale out of old ones, do not scour the market to find the best flue scraper or where a man can be got for $3.00 to take the place of a man you are paying $3.25, but remove the trouble and install a plant that will soften the water. It is an easy matter, usually, to prove the saving; if the management refuses to spend the initial sum, hammer away with facts about costs until they will spend it. One firm in this vicinity put in 200 tubes in two months at an everage cost in place of $7.50 per tube, a total of $1,500 for two months. A water softening plant of the proper size would cost about $8,000 and would pay for itself in two to three years.

The question of stokers should be carefully gone into and it will usually be found that there will be an undoubted saving in maintenance and improvement in service, especially in large plants. On quite small plants it is not necessarily advisable to install stokers.

Another and important item is the personnel of the force; the men, as well as the machinery, should work at high efficiency and good and intelligent men should be obtained, even if the price is somewhat higher than that demanded by inferior men. It would be easy to obtain common labor at $1.50 for an eight hour day as fireman, but if by paying $1.90 or $2.00 for the same service a superior workman can be obtained, the difference will be more than made up by the decreased use of coal and better service. In general, the organization consists of the head of the department controlling the various power houses, if there are more than one, or the power house and the general power distribution. Under him is a superin-

tendent for each power house and others for outside work. If the plants are large there may be a night as well as a day superintendent. Under the superintendent there would be, in large plants, a head to the engine room, another to the boiler room, etc. There should be distinct seniority of rank so that when the superintendent is absent there is no doubt about who is in control. If men work at high efficiency, their hours should not be too long. Power houses have of necessity to run twenty-four hours a day and therefore either two or three tricks must be used. If a man works twelve hours a day, takes three-quarters of an hour going to and returning from his home, another half hour for breakfast and supper and eight hours for sleep, he will not die of ennui in endeavoring to fill in the balance of the day. I am strongly in favor of three tricks of eight hours instead of two tricks of twelve hours. It is extremely difficult to get men of proper force of character to work on twelve hour tricks, but relatively easy to get men for eight hour tricks, even though the wages be less. In one of our power houses we were at first running twelve hour tricks and paying the enginemen $3.25 and were unable to keep them for any length of time. We later changed to eight hour tricks paying the enginemen $2.80 and one of the old men came back. When good men are obtained, treat them well so that they would rather work for you than for anybody else. If a man is sick on the three trick force, have his work taken care of by the other two men, with no deduction of pay or only partial deduction. This is an excellent practice where reliable men are hired, but is apt to be taken advantage of by the shiftless.

One of the best devices for the control of a power plant is the automatic recording instrument recording steam pressure, voltage, current, wattage, temperature on heating systems, pump speeds, etc., The most important in an ordinary power house are the steam pressure chart and voltage chart, the former records conditions in the boiler room, the latter, conditions in the engine room. The pressure line cannot be good unless the water level and fires are attended to, nor can the voltage line be correct if the switch board is neglected. It is excellent practice to require that a written explanation of any

irregularity in these charts be pinned to the chart, and an engineer or fireman with a too frequent repetition of bad charts should be discharged.

Another important point in connection with power house management is the avoidance of shutdowns. There is nothing more annoying to the public than a shutdown of the power plant of an electric railroad and there is nothing more costly to a producing firm than the shut down of the plant. Cost of making repairs is a secondary consideration, the first is continuity of service. Pipe lines should be so put in that any section in the power house could be cut out for repairs without shutting down the plant. A fairly large supply of duplicate parts should be kept on hand. All machines should be inspected at frequent intervals. If an engine has run for a year or more without repairing, the superintendent should rather have a nervous than a satisfied feeling concerning it.

A few points in connection with the compact and efficient power plant for the McKees Rocks shops of the Pittsburg & Lake Erie Railroad Co., may be of some interest. This plant is thoroughly up to date in almost every respect. It embodies a great many of the best features in power plant design. The building is 77′ x 100′ x 50′ high from the basement floor. Most of the pumps are in the basement. The main floor is divided by a brick partition wall into engine room and boiler room. The boilers are six Babcock & Willcox 264 H. P. each, nominal rating. They are, however, worked much above this rating. A load of 1,800 B. H. P. has been carried for several hours on four boilers. It was calculated that five boilers would at any time be sufficient to take care of the load, leaving one for spare. In connection with these boilers, I may say that we had a great amount of trouble at first from burning out tubes, 56 tubes requiring to be replaced in three months. When the water softening plant was installed and in good working order the trouble ceased and now the tubes remain almost as clean as the day they were installed. The coal and ashes are handled by machinery, the coal is dumped from hopper cars through a grating to a hopper beneath, whence it is hoisted by endless chain or conveyor to top of building, it is there dumped on a

horizontal conveyor which deposits it at points desired in the storage bins, whence it flows by gravity to stoker hopper. The ashes are handled from the basement by the same machinery and are dumped into a storage bin directly over the track, thence into hopper cars beneath. Coal capacity is 200 tons, ash capacity 2000 cubic feet.

The engines installed are four 14 x 24 x 14 Westinghouse compound engines, 280 R. P. M., about 250 H. P.

Generators are of the direct connected Westinghouse, 150 K. W. capacity, 240 volts.

The switchboard is an 18 panel board consisting of four generator panels, one load panel, five incandescent light and constant speed motor panels, three arc light panels and five variable speed motor panels.

There are fifteen pumps which cover every purpose and are of various capacities, from a 50 gallon test pressure pump to a 1,000 gallon cold water supply pump. Five of the pumps are motor driven centrifugal or turbine pumps.

The two air compressors are each capable of compressing 1,000 cubic feet of free air per minute to 100 pounds pressure.

There are also what are termed balancers or motor generators to split the 240 volt circuit into two 120 volt circuits for the arc lighting and six voltages from 40 to 240 for the variable speed motors.

This power plant takes care of the heating of the whole system of buildings, some of the buildings being half a mile from the power house. The heating is performed by circulating hot water through large heating coils in the various buildings, from which the heat is extracted by the air forced over them by fans. The temperature in all the buildings is controlled in the power house by raising or lowering the temperature of the water, which can be done at will. The water is heated in the power house in large heaters by means of exhaust steam supplemented by live steam, and is circulated through the system by two centrifugal pumps. It is expected that the heating load in 10° weather will, when all the buildings are up, be about 40,000,000 B. T. U. per hour, 40% of this being taken care of by the exhaust steam.

The steam pressure carried is 150 pounds, voltage 250 volts D. C., water pressure, general service, 80 pounds, fire service, 100 pounds, hot water supply, 125 pounds, test pressure, anything up to 400 pounds. About 4,000,000 gallons a week are used, and as 95% of this is double pumped, the pumps handle about 8,000,000 gallons a week.

Several of the automatic recording instruments referred to in the fore part of this discussion are in use in this plant. A few of the charts, and the explanations that accompanied them, are here reproduced showing the errors they detect. It will be noticed that in general the curves are very true so that the imperfections are very noticeable.

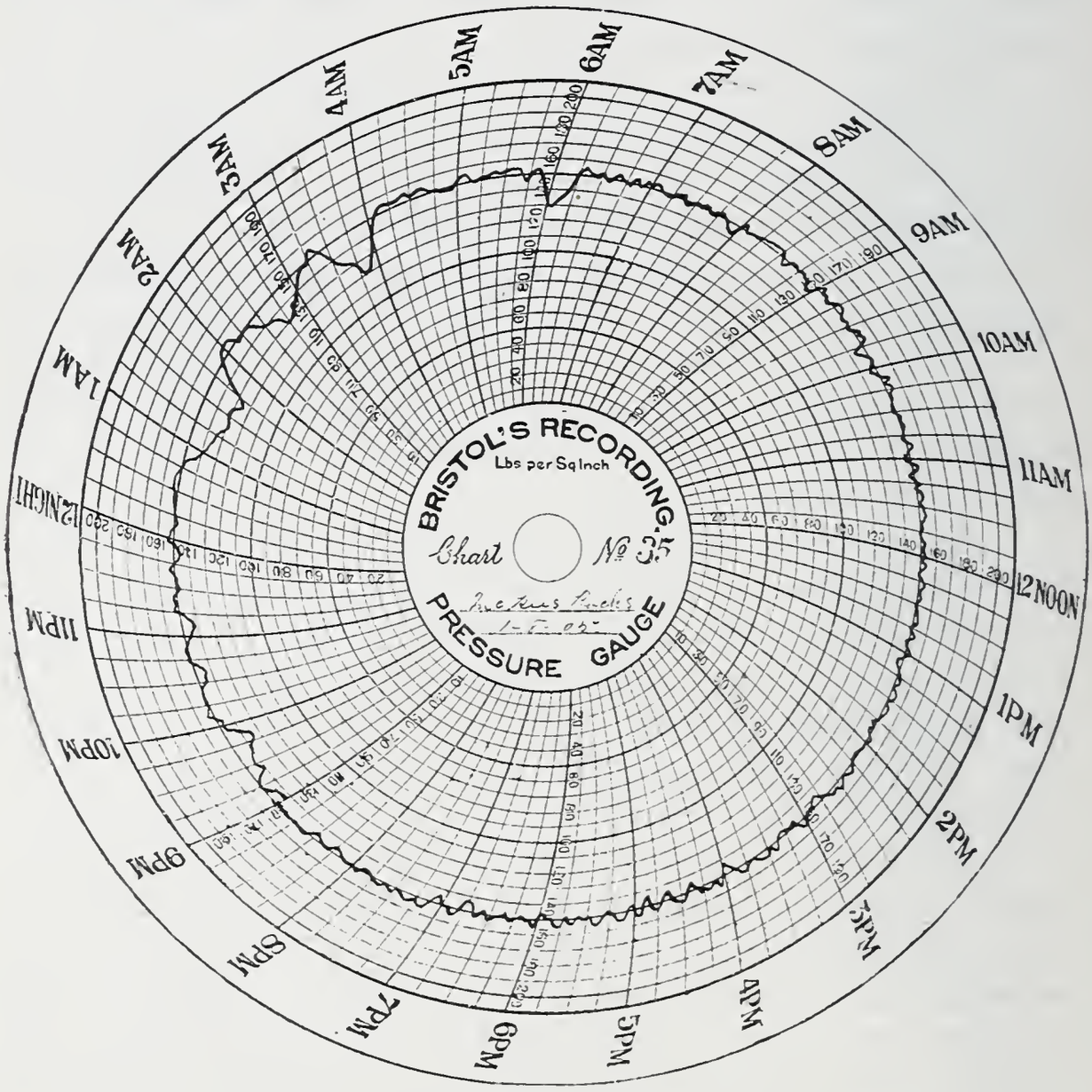


FIGURE 1.—"Fireman went to sleep. He was discharged."

A sample of the daily report sheet is here shown. The cut is made from the type written office copy, not from the original.

PITTSBURGH & LAKE ERIE RAILROAD COMPANY.

POWER HOUSE, McKEES ROCKS, PA.

REPORT OF OPERATION.

FOR 24 HOURS COMMENCING 7:00 A. M. April 29 1905.

	FIRST TRICK, 7 A. M. TO 3 P. M.	SECOND TRICK, 3 P. M. TO 11 P. M.	THIRD TRICK, 11 P. M. TO 7 A. M.
Engineman in charge	A. R. Ebersole.	T. McClintock.	W. J. Fleming.
Boilers, Nos.	#1, 2, 6	#1, 2 & 6	#1 & 2
Stoker engines, Nos.	#1 - 2	#1 - 2	#1
Feed pump, revolutions	1 619475 2 328556	1 625354 2 330051	1 630988 2 330051
Feed pump, hours run	1 6.30 2 1.30	1 8 2	1 8 2
Blow off, minutes	5@11.30	5@5.30 P.	5@5 A. M.
Coal, cars unloaded	D#37056	D#29198	0
Coal, cars on siding	D#29198	"	
Ashes, cars loaded	0	0	0
Compressors, hours run	1 8 2 7.45	1 8 2 4.40	1 1/4 2 8
Generators, hours run	1 2 8 3 8 4 8	1 2 1 1/2 3 8 4 8.05	1 2 3 8 4
M. V. balancer, hours run	1 2 8	1 2 1.40	1 2
Arc balancer, hours run	2/3	4.30	6.45
Gen'l water supply, hours run	Well River 7.40	Well River 1.30	Well River
Superheater, live steam, hrs.			
Cond'g heater, live steam, hrs.			
Bld'ng heaters, live steam, hrs.			

HOURS	8	10	12	2	4	6	8	10	12	2	4	6
GAUGES:												
Steam, live	151	148	151	151	158	152	150	150	154	151	151	151
Steam, exhaust	0	0	0	0	0	0	0	0	0	0	0	0
Fire service	100	100	100	101	100	100	100	100	100	100	100	100
Compressed air	101	100	100	99	102	98	95	100	100	100	105	100
Heating supply	39	off				38	38	38	38	38	38	39
Heating return	18					18	18	18	18	18	18	18
Hot water supply	100	100	98	101	100	98	98	100	100	101	101	100
Cold water supply	101	100	96	98	100	105	98	98	103	105	102	100
Locomotive testing			230	250								
Gen. service, low pressure	52	53	53	53	54	54	53	53	52	52	53	52
THERMOMETERS:												
Outside air	66	70	77	76	72	69	64	59	58	56	54	53
Machine shop					65		64		62		59	
Boiler feed, suction	58	58	58	59	58	59	59	59	60	59	60	60
Boiler feed, discharge	142		136		132		156		158		128	
Building heaters, supply	153	off				130	133	135	150	152	156	160
Building heaters, return	152					120	121	130	144	144	146	158
Condensing heater, supply	187	180	180	186	193	175	192	172	192	172	182	202
METERS: Wattmeter	Clr. #3					2676						2678
Wattmeter, load panel	31880				31899				31910			
Voltmeter, load panel	250	250	250	250	250	248	240	240	240	240	240	240
Ammeter, load panel	1300	1200	1200	1050	800	260	540	540	540	540	525	270
Ammeter, multivoltage	300	250	300	250	200							
Ammeter, arc lights							250	250	250	250	250	

Heating Fans, total hours run:—Mach. Sh., E. E. Mach. Sh., W. E. Paint Sh. 12 Boiler Sh. R. H. No. 1 R. H. No. 2

NOTE:—Readings of Wattmeter and of revolutions of feed pump to be taken at 7:15 A. M., 3:15 P. M. and 11:15 P. M.

REMARKS:— B.H.S. off 8 A.M. Repaired piston rods and packed valve stems #2 feed pump.

C. J. Jorden,
Superintendent.

The force at the power house consists of a superintendent who has charge of the men on three tricks, each trick consisting of one engineer, one oiler and one fireman; in addition,

there are during the day time two extra helpers. This is a very small force of men and the good results can only be accomplished on account of the large number of labor saving devices installed and the care and forethought expended on the original design. The plant is not yet worked to the limit, as

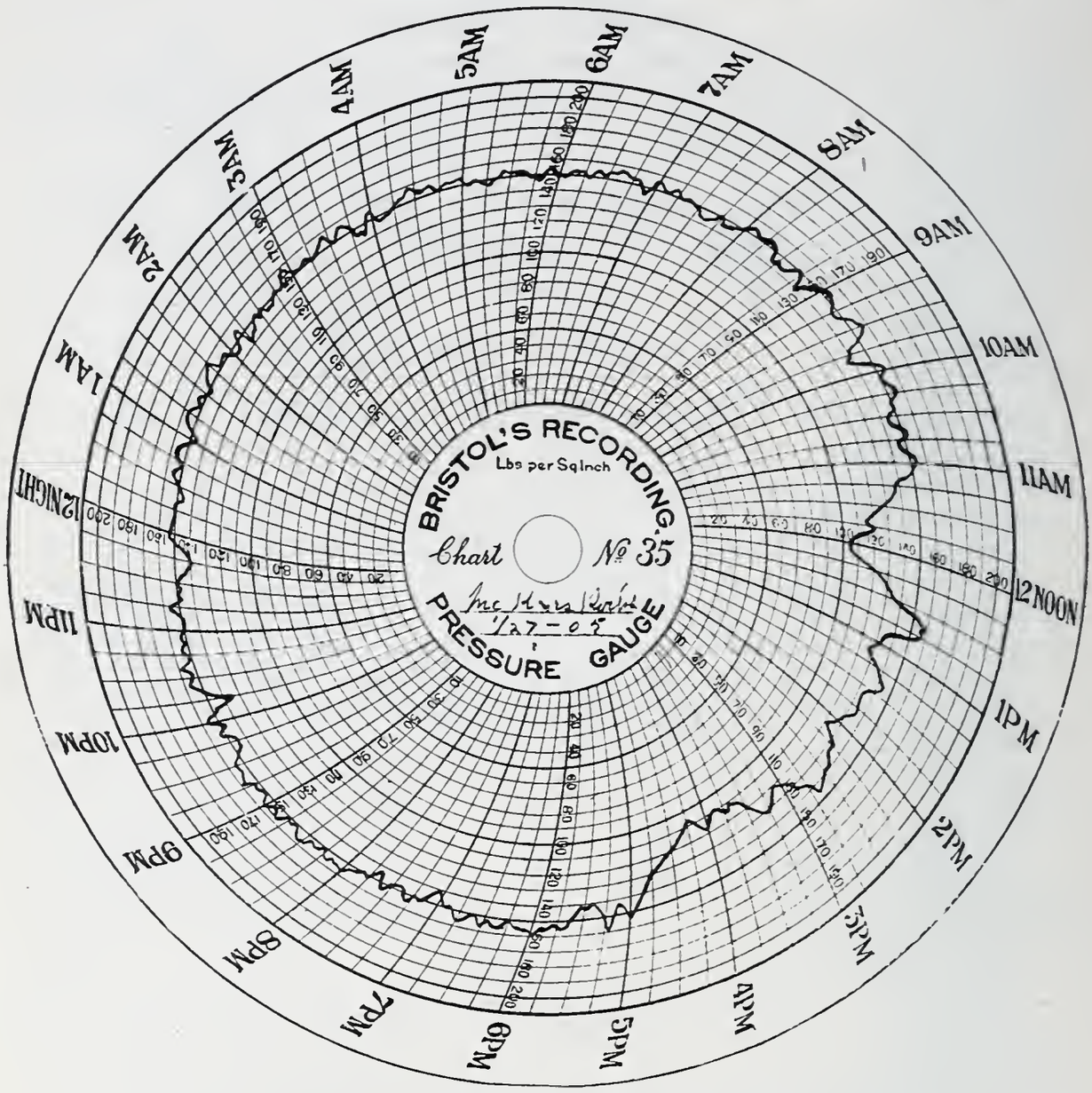


FIGURE 2.—"Drop on pressure gauge was caused by poor draft. Found combustion chamber back of boilers filled up with fine ashes. Took air blower and blowed ashes out. Combustion chambers are cleaned out when boilers are off. I find they need cleaning oftener. Have ordered night fireman to blow combustion chambers under boilers every night. I think this will keep combustion chambers free from filling up."

several new buildings have yet to go up, but from present appearances it would seem that it will accomplish what it was designed for. The plant is sometimes criticised on account of

the small electric units used, but the load varies very greatly. On summer nights one generator is sufficient to carry the load, while on dark days in winter all four generators are in service.

In proportioning the cost everything is based pro rata on the actual steam consumption, the steam consumption in most cases being based on result of tests.

An extract from the 1904 yearly report is as follows:

Pittsburg & Lake Erie Railroad Company, McKees Rocks Power Plant.

	Total	Monthly Average.
Steam Pressure, Pounds		148.3
Coal Consumption		
Cars, total	265	22.08
Pounds, total	22,724,400	1,893,700
Pounds per hour		2,592.1
Ashes, cars loaded	42	3.5*
Water Evaporated		
Gallons, total	20,910,000	1,742,500
Pounds per hour		19,373.2
Pounds per hour per lbs. of coal		
Actual		7.475
From and at 212° . .		8.662
Boiler H. P. developed . .		645.8

*Ashes were 13% by weight of the coal.

Expenses.			Per Cent.
Wages	$10,274.95	$ 856.25	50.27
Supplies	1,861.43	155.11	9.11
Machine Repairs	1,483.54	123.63	7.26
Coal	6,817.62	568.14	33.36
Total	$20,437.54	$1,703.13	100.00

General Distribution.

Heating	$ 3,208.01	$ 267.34	17.00
Compressed Air	5,464.66	455.39	26.31
Lighting	2,255.20	187.93	11.10
Pumping	4,779.69	398.31	22.78
Machine Tools, etc.	3,602.66	300.22	17.32
Locomotive Filling	1,127.32	93.94	5.49
Total	$20,437.54	$1,703.13	100.00

Rates.

Cost in cents, per	Maintenance	*Total
B. H. P. Hour, developed	0.367	0.752
K. W. Hour	0.628	1.286
H. P. Hour, electric	0.469	.962
1000 Cu. Ft. free air, comp.	1.695	3.474

Mr. Ralph Crooker, Jr., Mem. Eng. So. W. Pa.—I understood the speaker to say he had but 13% of ash from the stokers of his boilers. I would like to know how he accomplished that. It is better than I am in the habit of seeing.

Mr. G. M. Campbell—That is based on estimate. I would not say that it is exactly right. The coal is correct. Every car of coal that goes in is weighed. The average car of coal that we get weighs about 90,000 lbs., and, using the same cars, we judged from some experimental data we obtained concerning weight of ashes that they ran about 70,000 lbs. The ash we get is good. There is very little combustible in it.

Mr. Charles Fitzgerald, Mem. Eng. So. W. Pa.—If our memory serves us aright we have a test where we used slack coal on a Murphy stoker and the ash came down even below Mr. Campbell's figure. Our coal cost us 70 cents a ton delivered, and our average horse power was about 650 for 20 hours. We used Murphy stokers and return tubular boilers. When we started we had trouble, but after considerable experimenting we got our firemen so they knew how to handle the slack coal and our ash was gotten down to the minimum.

*Based on cost of plant of $165,000, 5% interest and 8% depreciation.

It seemed that we got as good work out of the ordinary slack coal as we could out of run-of-mine, crushed, or any high grade coal.

There are some things that I used to make a hobby of. One is cleanliness in the power house. The first thing I try to do with an engineer is to have him clean himself. Polish-

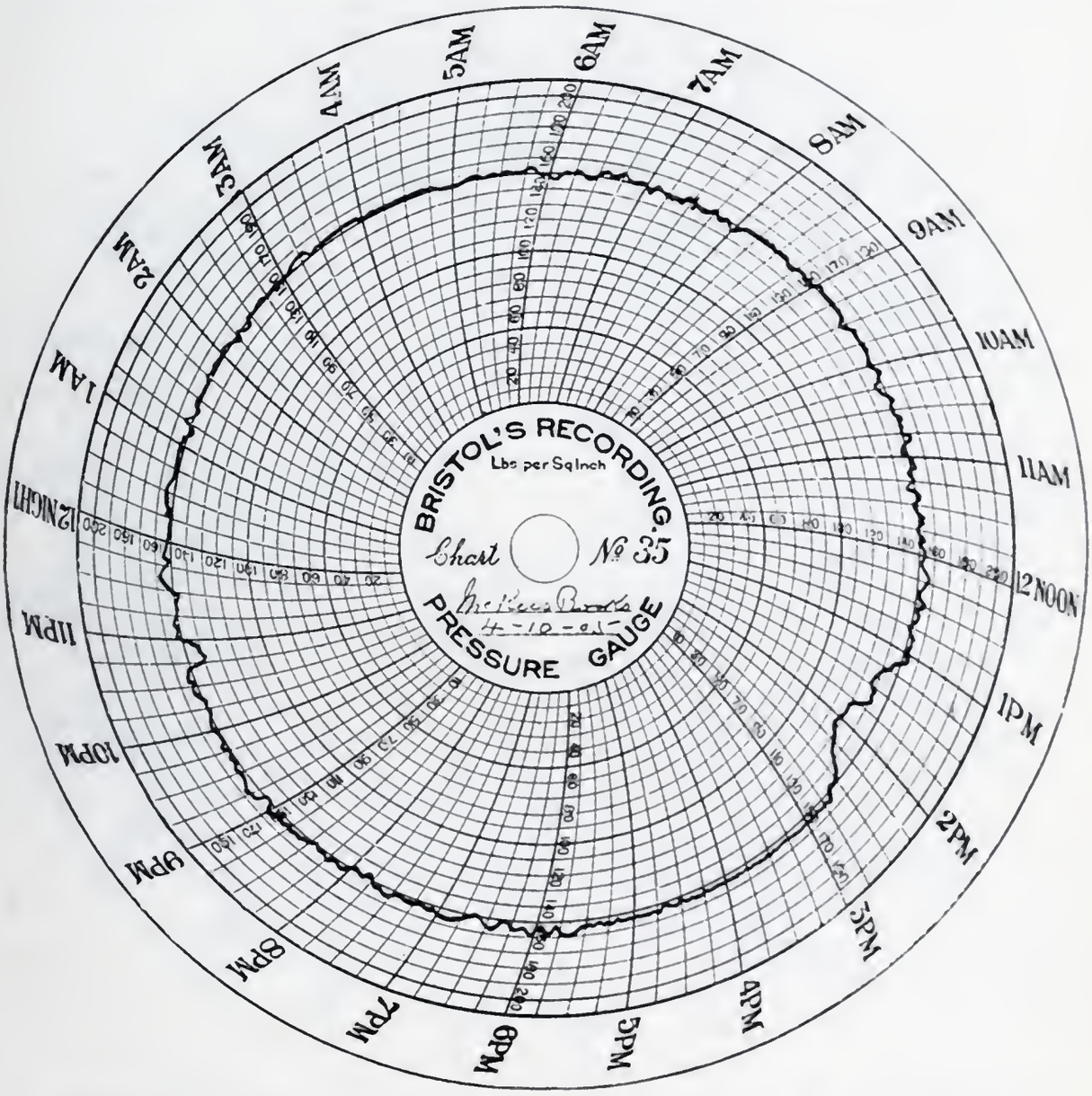


FIGURE 3.—"Cause of bad line on pressure chart was from an unexpected load, 1,850 Amperes. A very heavy storm was passing over McKees Rocks at the time, and the fires were not very clean."

ing the bright work is never satisfactory to us, we also want the corners of the engine and boiler rooms clean. If you instill that into your engineers they will soon commence to take pride in their work. Unless a man is clean and tidy about the place we don't think you will ever get good records from him.

We are firm believers in recording charts, steam, vacuum, coal, and so forth. We had quite an experience in the last two years in the operation of a hydraulic dredge. We used charts for the suction, and could go around the dredge once a day and look over the charts and know whether the men had been simply pumping water or pumping sand. We kept records

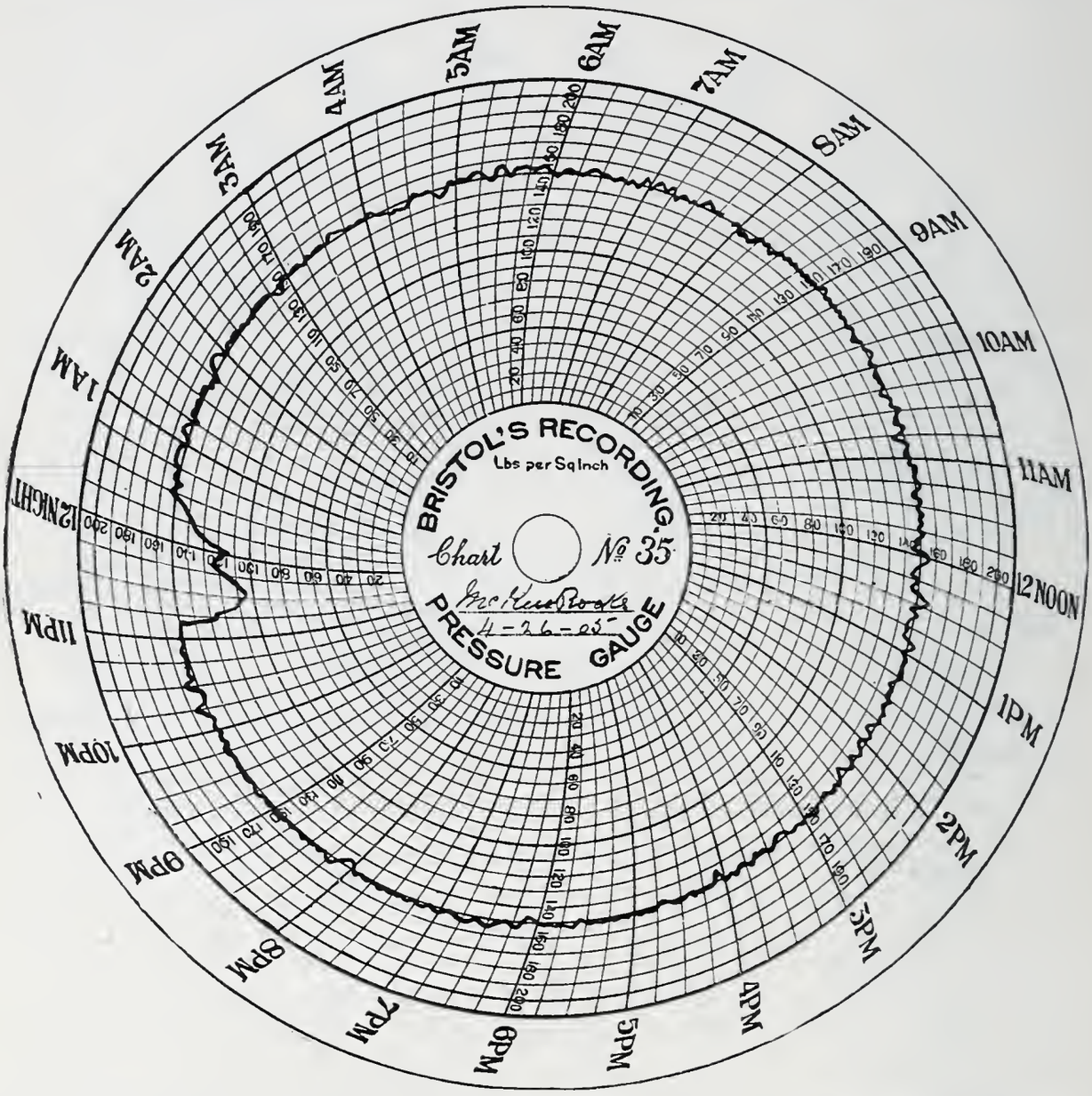
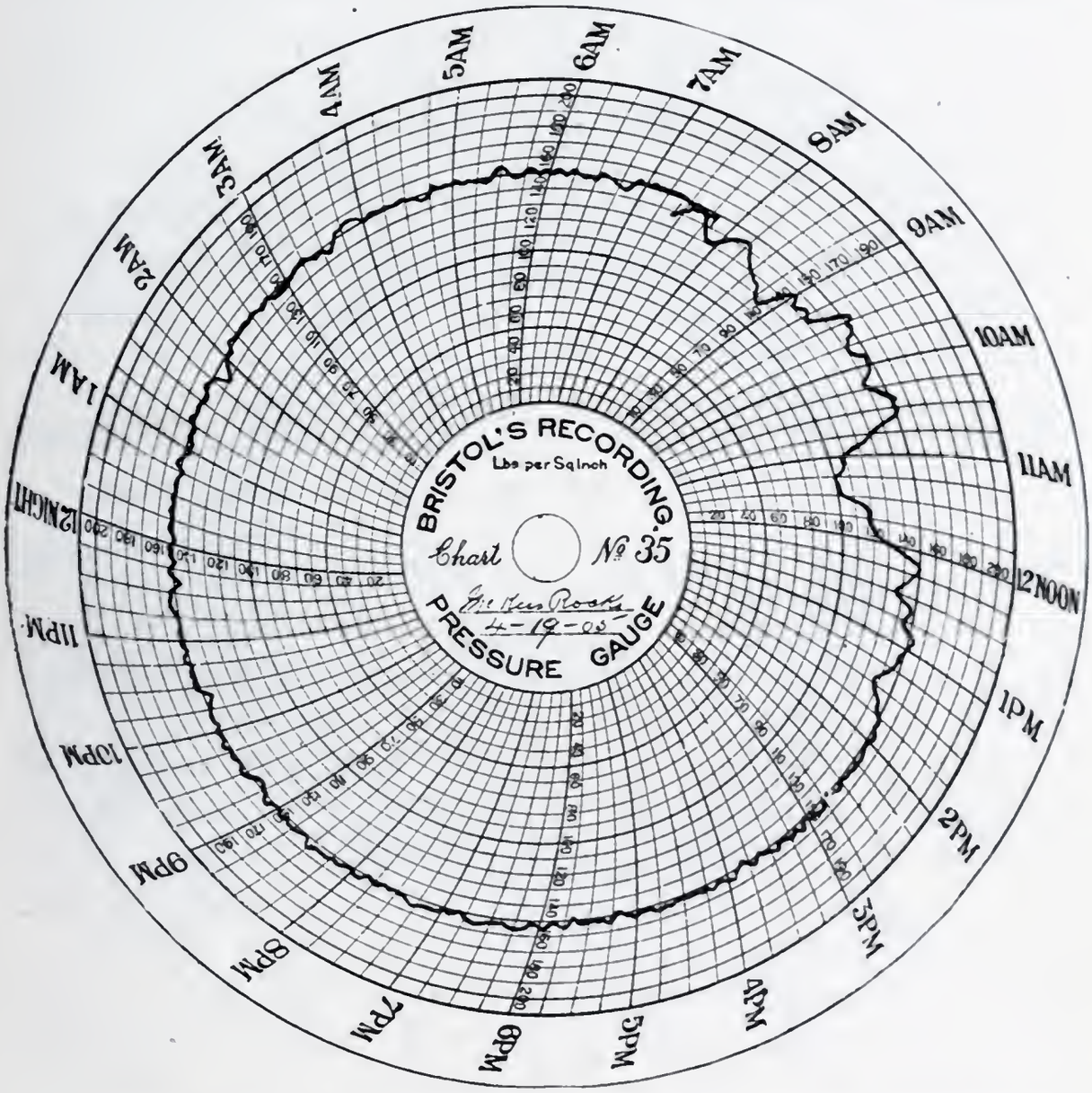


FIGURE 4.—"Bad line on pressure chart 11:10 P.M. was caused by bursted tube in Boiler No. 4, 7th row and 6th tube."

for many years at the 34th street and 47th street power stations. We had water meters and they were comparatively accurate. Then we had a space arranged in front of the boilers where every wheelbarrow load of coal was weighed and checked. The ashes were weighed once in a while simply as a check.

I was able to report to our directors at the end of the year exactly how much of each kind of oil we had used, how much waste, packing, etc., and show them the cost per horse power for each one of these articles. I presented it to them the first year—and it was asked for after that.



FIGURES 5 AND 6.—"The bad line on pressure chart was caused by letting too much coal in furnace."

MR. J. N. CHESTER, Mem. Eng. So. W. Pa.—What we say will be from the standpoint of a superintendent of power stations consisting almost entirely of water works from 25 to 600 H. P. And, unfortunately, not of stations that we have been able to build as we would have them.

The question of records has always been to our minds a very grave one, as to what extent it can be carried and not be a detriment to the plant. With large plants there is no doubt that the system we have heard described is a profitable one. But apply this to smaller plants it will ride your horse to death. It was well expressed by a large contractor who

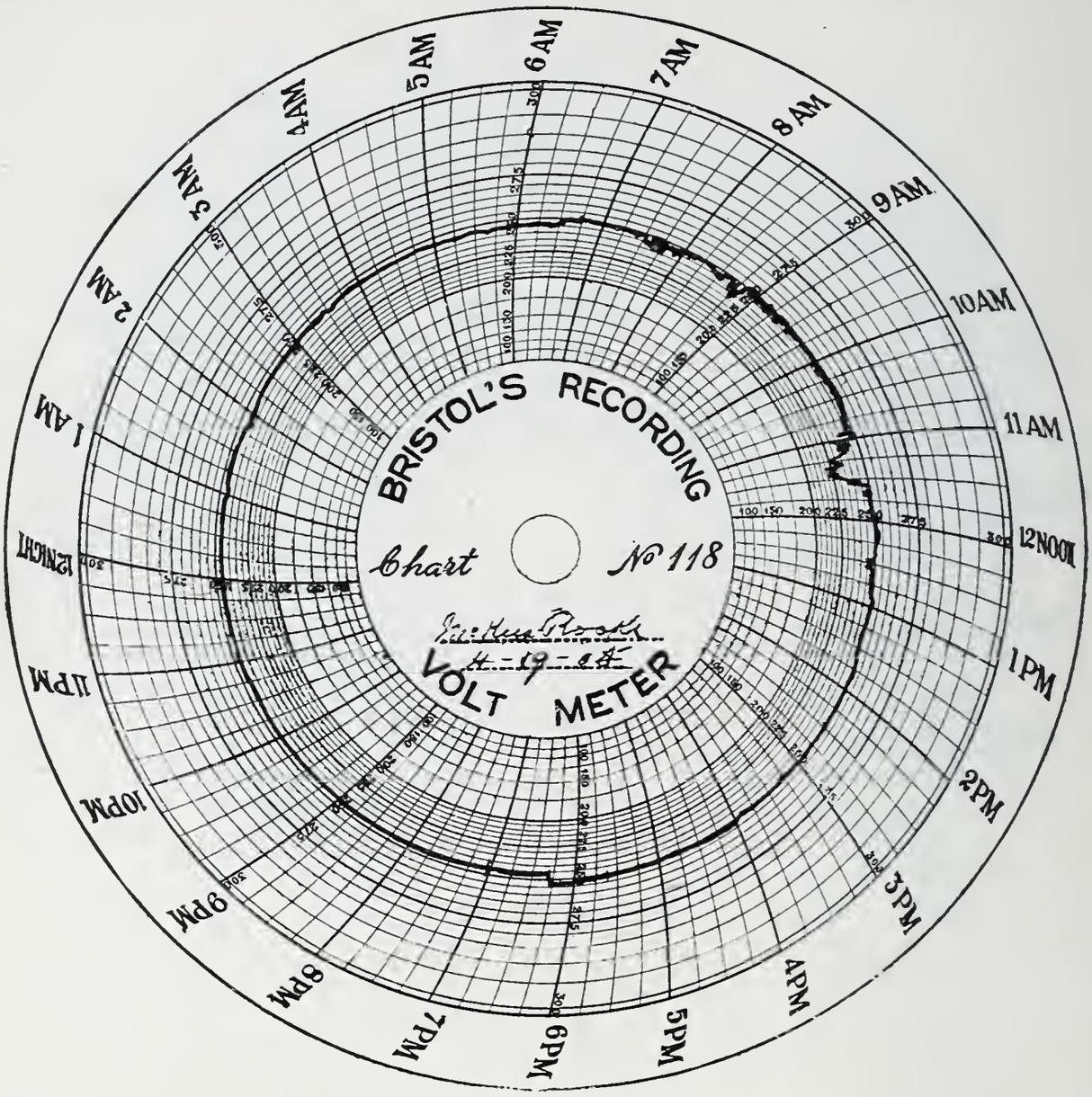


Fig. 6. (See Fig. 5.)

accounted for his high bid as against another contractor who did not do work on so magnificent a scale, by saying, "He carries his office in his pocket. He hasn't any fixed charges and can make money at a price where we would lose."

It is the same with a small plant. If you add a system of records you will have to add another clerk in the local

office and two or three in the general office to tabulate them, and the clerk hire will more than eat up any saving you will make. We are a firm believer in records and apply them more or less according to the size and general make up of the plant in question.

Our experience has been that the grade and cost of oil can be varied considerably. In an old high pressure or compound non-condensing pump with $3\frac{1}{2}$ expansions we would not expect to use the same quality of oil that we would in a cross-compound or triple expansion pumping engine with 21 expansions. We feel that to pay over 22 cents or 23 cents a gallon for cylinder oil for compound non-condensing and high pressure pumping engines is over-stepping the limit of economy; while for triple expansion engines with 21 expansions we would hardly feel that we could get good enough oil. Another thing is the quality of the steam that enters the cylinders. We can't find a great saving in mixing high class oil with low class steam. We must consider the temperature of steam above the point of saturation in the selection of oils. Superheating of steam is going to cut quite a figure in the quality of oil used. If we had an elaborate plant we would wish to fit it up with every convenience, but if an old water works built prior to the days of cranes, condensing apparatus and the many conveniences of to-day, and many times where the H. P. is less than 100, these conveniences might cost more than the necessities.

Stations which we would design to-day with 200 to 400 H. P. or even less, would include cranes. The type of machinery to be installed under these cranes would be given consideration. Vertical machinery along rivers that rise and fall to a great degree, as in this part of the country, and horizontal machinery where we can pump water at the same head, having the same horse power as we have with a vertical engine and reducing the weight of our machinery one-half to two-thirds, are features that have something to do with investing in a crane. In numbers of stations that we operate the crane might cost more than the station. No matter how large your organization is you have to put each plant on its

own basis and your directors and investors are going to look over the balance sheets at the end of the year and look for as large a percentage of profit in the smaller plants as there is in the larger ones, and if you have as many conveniences in the smaller plant as in the larger, you may show a minus quantity for profits in the smaller plant.

The personnel of the men is something that we have tried to study. In the first place we give a man leeway enough to make him feel that he is some one, that he is a factor in the company, and still to an extent keep down his movements, and govern his actions, so that he will not overstep the bounds of the authority that should be delegated to him.

The vices that we encounter might be summed up as dishonesty, laziness, procrastination and superstition. They are not all possessed by any one, and we can be thankful that there are a great many that possess none. By dishonesty we do not mean serious things but little items that tend to annoy. For instance we weigh coal and tabulate the records and put one fireman against another. That man has pride and he very soon conceives the idea that by handing in short weights he can make a better record. And in our experience they will do it. When you come to check up your coal receipts against the weights of coal consumed you will find a leak that is hard to locate. Then we buy our coal by mine weight and if we check coal consumed against mine weight, unless we allow for the customary losses in shipping coal, we are going to think our fireman dishonest whether he is or not.

Another form of dishonesty is that feature introduced, and fostered by the material men in the little attentions, such as presents, courtesies, dinners and theatre parties, they give to our engineers, always tending to breed in the men a leaning to favoritism. The engineer does not intend this for dishonesty but nevertheless it will sooner or later take that form. In our experience it has been found necessary to bar from the engine room the dictation of what shall be purchased in the way of supplies. But in so doing you are in a measure

killing what might, if properly built up, become a valuable feature in the employe.

Laziness and procrastination generally occur in the same individual. The tendency to not do things at all or to put off until tomorrow what might be done to-day. Especially in the small power house where the fireman hasn't enough to do, as where you originally started with a small water works and one man to attend to the pump and fire the boilers. Then the station grows to where it is too much for one man and not enough for two—and you generally find that with the two it is not then as well taken care of as it was with the one who had too much to do.

Generally, in the smaller towns they still have the old fire pressure requirements, that when a fire breaks out you must double your pressure. That sometimes means multiplying your horse power by four. The machine is purchased for its economical design in what we still term domestic pressure. When fire pressure is needed we must not only double our horse power but cut the efficiency, or economy, in half. Then we need a larger number of men, larger boilers and a surplus of energy generally going to rust.

Superstition—this objectionable feature takes the form of a belief that certain things that should be well known physical facts cannot be done; that one engine or pump similar to another will not perform the same service, or the excusing of the bad action of a machine by the simple assumption that it's contrary. While we will allow that there is something in the "innate cussedness of material," we believe that it seldom exhibits its temper to any marked degree and always argue with our engine room employes that we have reason to expect certain results and when they are not forthcoming we should know why and not attempt to blame the machines or to excuse the shortcomings in any way other than by a thorough investigation and analysis of the difficulty.

In water works service shutdowns cannot be tolerated. Cities in contracting for fire protection and for service generally, insert a clause which cancels the franchise whenever it can be shown that by negligence the supply of water has

been shut off when it could have been avoided. Recent court decisions say that it is not enough to show that precautions have been taken but that extra precautions should have been taken to prevent any shutdown.

One thing we noticed in connection with the charts exhibited is that the excuse for a bad run was written on a piece of paper and pinned to the chart. We require the excuse to be written with an indelible pencil or ink on the back of the chart. We sometimes get into court and such an entry goes as evidence, which we doubt if the paper attached to it would.

Mr. J. J. Muir, Mem. Eng. So. W. Pa.—One thing we wish to emphasize is cleanliness. Where there is dirt there will be disorder, and where you find disorder you find inefficiency, not only in the men but in the machinery.

We find also that a great deal of trouble, where you have many repairs, is that they have not been done in an efficient manner. They have been done hurriedly, or in a slip shod manner. It is very hard in many instances to get men in charge of machinery to appreciate that it is really a saving to themselves in the long run, besides tending to the efficiency of the plant.

We think the indicator can be used to great advantage, if used regularly and not spasmodically. A slight disorder in the working of the engine can often be detected by the indicator diagram. In power plants the indicator is just as important as the steam chart or any other chart.

In plants where firing is done by hand, firemen tend to, and often are allowed to fire irregularly, both as to intervals and quantity of coal shoveled in. It is very difficult to get men to understand that such irregular working of the fires results in inefficiency, and causes shortage of steam where there is no surplus boiler power. I believe such inefficiency in hand firing is largely accountable for the adoption of mechanical stokers.

We are firmly of the opinion that in many instances it pays to give a little higher price to get a proper quality of oil, particularly in the cylinders. In many power houses the system of pressure feeding of bearings and all working parts

obtains, and this tends to economy. We think that a cheaper grade of oil can be used and the oil can be used over and over again, though there is of course a certain amount of loss to be made up.

Very often the surface condenser can be installed to advantage, and will eliminate the trouble from incrustation of the boilers. In many instances the quality of the water makes it impossible to use the water from a jet condenser for boiler feeding. In such cases it would be necessary to adopt some means of purifying the water; the surface condenser avoids the necessity of this.

Mr. J. N. Chester—Have you successfully accomplished the extraction of the oil?

Mr. J. J. Muir—That is being done right along in marine practice.

Mr. J. N. Chester—Have you been able to accomplish it in your ordinary practice?

Mr. J. J. Muir—No, I can't say that I have.

Mr. R. H. Danforth, Mem. Eng. So. W. Pa.—A large number of marine engines run without any oil at all in the cylinders.

Mr. J. N. Chester—And where they use a certain amount of oil in an engine we use thirty times that amount in the same size engine.

Mr. Charles Fitzgerald—We had some experience with a 1,200 h.p. triple expansion marine engine. We started off with engineers not acquainted with marine work. During my absence they commenced to dose the oil pretty lively. We had occasion to go inside of the boiler and found considerable oil around the water line. The only thing to do was to get a couple of marine engineers who understood the use of oil in marine practice.

There are many grease extractors in the market but none are satisfactory. There is only one sure way and that is not to put too much oil in the engine.

Mr. Ralph Crooker, Jr.—I think no one who has used a water purifier would ever think of using a surface condenser as a substitute for it. I know of no better practice than puri-

fying water before you put it in the boiler, especially where you have to contend with sulphate of lime, you can save money in the installation of your plant by putting in a purifier.

Mr. R. H. Danforth—On a torpedo boat test we use picked coal and fire it by hand and get results in the way of evaporation and coal burned that would knock a stoker into the next county. We have four or five men in the boiler room and one of them is responsible for the whole test.

Mr. Charles Fitzgerald—What amount of coal do you burn per foot of grate in these tests?

Mr. R. H. Danforth—American torpedo boat practice is to use about 60 to 65 lbs. coal per sq. ft. of grate, or about 1.50 lbs. I. H. P. hour of engines.

English practice as shown on a 12 hour trial of H. M. S. "Ardent," built by Messrs. Thornycroft calls for 71½ lbs. coal per sq. ft. of grate per hour, 1.53 lbs. per I. H. P. hour, and 37.93 miles run per ton of coal. Test was run in spring of 1896.

Mr. Charles Fitzgerald—The speaker took charge of the 34th street power house in 1889 and ran it until 1897, and in that time there had not been a boiler failure, nor a crack, nor a tube taken out, nor was there in any part of those boilers an ⅛ inch of scale. We attribute the success of those boilers, as far as repairs were concerned, to the stokers. We believe that what tears boilers to pieces more than any other cause is opening the door with a hot fire and allowing a cold blast to strike the sheet. With a stoker you keep a regular temperature. When we cooled those boilers down we would simply let the fire go out and keep everything closed from Saturday night to Monday morning; and firing up we would take, if possible, twenty-four hours to bring the boiler up to pressure.

Mr. J. C. W. Greth, Mem. Eng. So. W. Pa.—There is no question that water free from scale forming and corroding substances will keep the boilers clean and make them last longer. Of course, means can be introduced into the boiler to prevent the formation of scale or corrosion, but you then have in suspension a muddy insoluble mass of the compounds introduced, together with the substances in the water. You

have merely changed their state, but not removed them. A feed water heater will not take out more than 50% of the carbonates of lime and magnesia in the water. This figure is based on a long continued series of experiments with different waters. As far as the sulphates and acids are concerned, the ordinary heater will not affect them at all. The sulphates of lime and magnesia can be removed partially by the live steam heater. To remove them, however, in sufficient quantity to make the employment of a device of this kind valuable, concentration is necessary. This, however, cannot be accomplished in this type of apparatus. We have frequently analyzed blow off waters from boilers showing as high as 25 grains of calcium sulphate in solution. This proves that concentration as well as heat is necessary to precipitate the sulphates of lime and magnesia. Of course, the sulphuric acid cannot be removed by heating alone. The only rational method of supplying boilers for the greatest economy, is to supply them with water free from scale forming and corroding substances. This can be readily accomplished by many of the water softening and purifying systems on the market to-day. The steam boiler is the heart of the steam plant, the part of it which usually gets the least attention, and on which the greatest economy can be effected.

The cost of producing steam is lowest with the purest water. This holds true for fuel consumption, labor and repairs, and if you can supply your boilers with pure water you will reduce the cost of operating your power plant accordingly.

Mr. G. M. Campbell—The question of cylinder oil has been criticised rather sharply. We have used only the better grades of oil and have found that the better the grade of oil used the less the cost in the end.

It is very important that pumps do not shut down. Even in our plant at McKees Rocks, we think it so important that the service be not interrupted that we have cranes over the pits where we pump from the river so we can rip out a pump that fails and put in another from some other part of the

plant, which we could not do, in the time required, if we had to use jacks.

We find that if you make up a blank report where everything is filled in excepting the numbers, the men can put all figures in in a very few minutes; if you give them a blank sheet and ask them to make you a report of what they do, not one man in twenty-five of the ordinary workmen can do it. We get many reports from all over the road every day, and they are filled in correctly.

The only way we can check the supplies is to check one power house against another. If one man declared a certain packing no good, it would not do to force it on him, for he would get the better of you in the end. But if one of the other power houses uses it and thinks it the best thing out, then it cannot be altogether bad in the first.

It is not every man that can take an indicator diagram. We think they are excellent and do it occasionally, but it is not part of our regular routine; it is generally done by an extra man who is better able to do it than the ordinary power house employe. Unless you know under what conditions a diagram was taken, it is not very valuable.

The Allegheny River in 1897 was decidedly better than it is to-day, and what was good practice from 1889 to 1897 would not necessarily hold good to-day. The water at that time was largely carbonate, while now it is running to acid. A heater would remove nothing from the Monongahela River for there is no carbonate there at all. Last fall there was as high as thirty grains of sulphuric acid per gallon in Youghiogheny River water. That was entirely taken out by our water softeners.

Engineers' Society of Western Pennsylvania.

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS

The two hundred and fifty-sixth regular meeting of the Engineers' Society of Western Pennsylvania was called to order in the lecture room of the Society's House, 410 Penn Avenue, Pittsburg, Pa., Tuesday, June 20, 1905, at 8:30 P. M., with President Diescher in the chair and 24 members and visitors present. The following gentlemen registered:

MEMBERS.

C. B. Albree,
Louis P. Blum,
Samuel Diescher,
N. H. Finley,
E. Fitts,
Gerald E. Flanagan,
J. M. G. Fullman,
Wm. Judd,
Robert Linton,
Geo. P. Maury,
F. V. McMullin,
H. W. Myer,
C. T. Myers,
Fred Schatz,
F. Z. Schellenberg.

VISITORS.

John Burton,
W. J. Montgomery.

As the minutes of the last meeting were in print and in possession of the members, and there being no objection to so doing, their reading was dispensed with.

The report of the Board of Direction was read by the Secretary, recommending for membership 6 applicants.

On motion the Secretary was instructed to cast the ballot of the Society for their election.

It was announced that in consideration of his 25 years' service as Treasurer of the Society the Board of Direction had appropriated $100 to purchase a Life Membership for Prof. A. E. Frost.

The President announced the death of John Wesley Anderson. On motion it was ordered that a committee be appointed to draw up resolutions on his death.

A paper on "Outlines of Mine Ventilation" was then read by Mr. Wm. Clifford, Member of Engineers' Society of Western Pennsylvania.

After discussing the paper the meeting adjourned at 10:30 P. M.

F. V. McMullin,
Secretary.

NEW MEMBERS.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY
MURRAY FORBES,	Mgr., Westmoreland Water Co., Greensburg, Pa.	W. C. Hawley, George R. Harlow, Morris Knowles.
BENJAMIN WM. STONE,	Gen'l Foreman, Westinghouse Electric & Mfg. Co., Lock Box 123, Turtle Creek, Pa.	Henry D. James, S. M. Kintner, P. M. Lincoln.
CLARENCE E. WATTS,	Mech. Eng., Berwind-White Coal Mining Co., Windber, Somerset Co., Pa.	F. I. Kimball, Harry J. Lewis, F. V. McMullin.
PAUL L. WOLFEL,	Chief Engineer, American Bridge Co., Ambridge, Pa.	Emil Swensson, A. H. Nelson, J. K. Lyons.

MONTHLY MEETING OF BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at the Society's House, 410 Penn Avenue, Pittsburg, Pa., Saturday, June 17, 1905, at 8:30 P. M.

Present, Messrs. Diescher, Flanagan, Lyons, Knowles, Schatz, Stucki, Maury and Secretary.

The following resignations were accepted:

Bertram M. Kershner, B. E. Tinstman.

Treasurer's report:

Building Fund	$1,302.32
Dormant Fund	3,617.59
Checking Account	4,420.85
Total	$9,340.76

Secretary's report:

Membership June 17, 1905, 944.	
Collections May 13 to June 17, 1905 ..	$ 565.35
Previously reported	6,175.24
Total, 1905	$6,740.59
Payments to June 17, 1905	3,865.96
Bills were paid aggregating	320.79

On motion $100.00 was appropriated to pay for a Life Membership for Prof. A. E. Frost in recognition of his 25 years' service as Treasurer of the Society.

On motion the following resolution was passed:

WHEREAS, The attention of the Board has been called to the fact that an attempt has been made by a member to advertise his wares at a meeting of the Society.

Resolved, That the Board desires to call the attention of the members to the fact that it is unwise in referring to particular devices or apparatus to call attention to the name of manufacturer, agent or price, or to distribute advertising literature or otherwise call attention to the commercial factors of the article as provided by Article IV, Section VIII of the By-Laws, and that the Secretary see that this resolution be brought to the attention of the members.

The Committee investigating the advertising contract presented a preliminary report which, on motion, was ordered accepted and filed.

On motion the Secretary was ordered to notify Mr. F. A. Ensign that the Board considered his contract to expire Sept. 1, 1905.

On motion the Secretary was ordered to publish no numbers of the Proceedings during August and September.

On motion the Board adjourned at 10:30 P. M.

F. V. MCMULLIN,
Secretary.

SPECIAL MEETING OF THE BOARD OF DIRECTION.

A special meeting of the Board of Direction was held at 410 Penn Avenue, June 30, 1905, at 8:30 P. M., to consider the subject of the advertising in the Proceedings. Present, Messrs. Diescher, Flanagan, Kintner, Lyons, Whited, Knowles, Barnsley, and Secretary.

A suggestion having been made that this Society exchange publications with the members of the Engineers' Club of Philadelphia, the Western Society of Engineers and the Association of Engineering Societies, on motion the Committee on Advertising was instructed to correspond with these various Societies with the view of learning the practicability of the scheme.

On motion the Committee on Advertising was instructed to contract for the publication of the Proceedings, beginning with October, 1905, and report the contract back to the Board for approval.

On motion the Committee on Advertising was authorized to contract for advertising in the Proceedings beginning with the October number, 1905; all contracts to be taken subject to the approval of the Board.

On motion the Committee on Advertising was authorized to insert in suitable places in the July number, 1905, of the Proceedings, notices that in the future the Society would conduct its own advertising.

On motion the meeting adjourned at 10:15 P. M.

F. V. McMullin,
Secretary.

CHEMICAL SECTION.

The regular monthly meeting was held with the Pittsburg Section of the American Chemical Society in the Society House, 410 Penn Avenue, Thursday evening, June 22, 1905.

The meeting was called to order at 8:30, Chairman G. P. Maury presiding. Twenty-one members and visitors were present.

The minutes of the May meeting were read and approved.

Mr. William D. Brown read a paper entitled Potassium Percarbonate, explaining its manufacture and properties. After discussion the meeting on motion adjourned at 9:10.

HARRISON W. CRAVER,
Secretary C. S.

OUTLINES OF MINE VENTILATION.*

BY WILLIAM CLIFFORD,
Member Engineers' Society of Western Pennsylvania.

By the outlines of ventilation, we mean the broad practice of the art as applied to produce a safe and sanitary atmosphere in the underground workings of a coal mine.

We do not propose to treat of gases met with in a coal mine, or of the principles which underlie the laws of ventilation, as these are well known and have been fully set forth in text books and transactions of our mining institutes.

Whenever man is removed from his natural habitat, the open air, the change must be met by some artificial means. We ventilate our houses and public buildings, because if we failed to do so, the noxious carbonic acid gas, CO_2, generated by our breath and the burning of fuel for light and heat, would soon deprive us of vital energy, and from persistent deprivation of fresh air, and closeness of space, sleep and death would ensue.

In mines, (particularly coal mines) explosive, poisonous, and irrespirable gases are thrown off, and it is the province of ventilation to remove, or to dilute so as to render harmless, these gases.

The principal gases met with in coal mines are CO_2 and CH_4; CO and HS_2 are found occasionally, the former given off by mine fires, and the latter resulting from the imperfect combustion of powder.

Little difficulty seems to have been experienced for want of ventilation in early drift workings, which were mere primitive burrowings along a narrow fringe of outcrop, but towards the end of the 17th century, shafts became common in the Midland counties of England.

It was to such shafts that the earliest device for giving rise to a wind, by means of a water fall, was applied. The water

*Meeting of the Society, June 20, 1905.

was allowed to run over the edge of a large bucket, or to fall on a flat surface, so as to split it up into numerous small streams, or ducts, before it fell down the shaft. This created a feeble wind in the direction of the falling water, supplying the vital air for the breathing of men and animals employed below.

The next step was the fire pan, or basket, consisting of an iron crate suspended at one end of a chain, the other end being fastened to the barrel of a windlass at the top of the shaft. This fire basket, being lowered to near the bottom of the shaft, the air above it was heated, the change of density causing it to rise and set up circulation which continued so long as the fire was kept burning. The feeble current thus set up was suitable only for small mines.

In sinking shafts a bellows worked by hand and delivering air into a tube, reaching nearly down to the bottom of the shaft, was used.

Later the fire pan, or basket, gave place to a furnace fixed near the bottom of the shaft, by which a continuous and greatly increased volume of air was obtained. The evolution of the mine furnace is a most interesting subject, its latest form being designed to rarify large volumes of air with great regularity. Many furnaces in deep shafts produced over 100,000 cubic feet of air per minute and some of them much more. That at the Oaks Colliery, at the time of the disastrous explosion in December, 1866, moved 157,000 cubic feet of air per minute, while at Hetton Colliery, County of Durham, England, 208,000 cubic feet of air per minute was moved by three furnaces placed at the bottom of the shaft 300 yards deep.

The most remarkable example of furnace ventilation, the writer believes, still in operation, is at Murton Colliery, Durham, England. The shaft is 498 yards deep. The volume of air passed is about 500,000 cubic feet per minute. To rarify this vast volume, three furnaces of huge dimensions are used, and twenty-seven boilers used for generating steam for hauling, pumping and other purposes, throw their heated products of combustion into this furnace shaft, greatly increasing the motive column.

Ashton Moss Colliery in Lancashire, England, with a shaft nearly 1,000 yards deep, is ventilated by a furnace. The writer

has no statistics of the ventilating of this colliery, but from personal observation, he would not think it approached in volume many of the better furnace ventilated pits in the County of Durham.

At 1,000 yards deep, with well designed furnaces, the economy should approach, if not reach, that of any of our best modern fans.

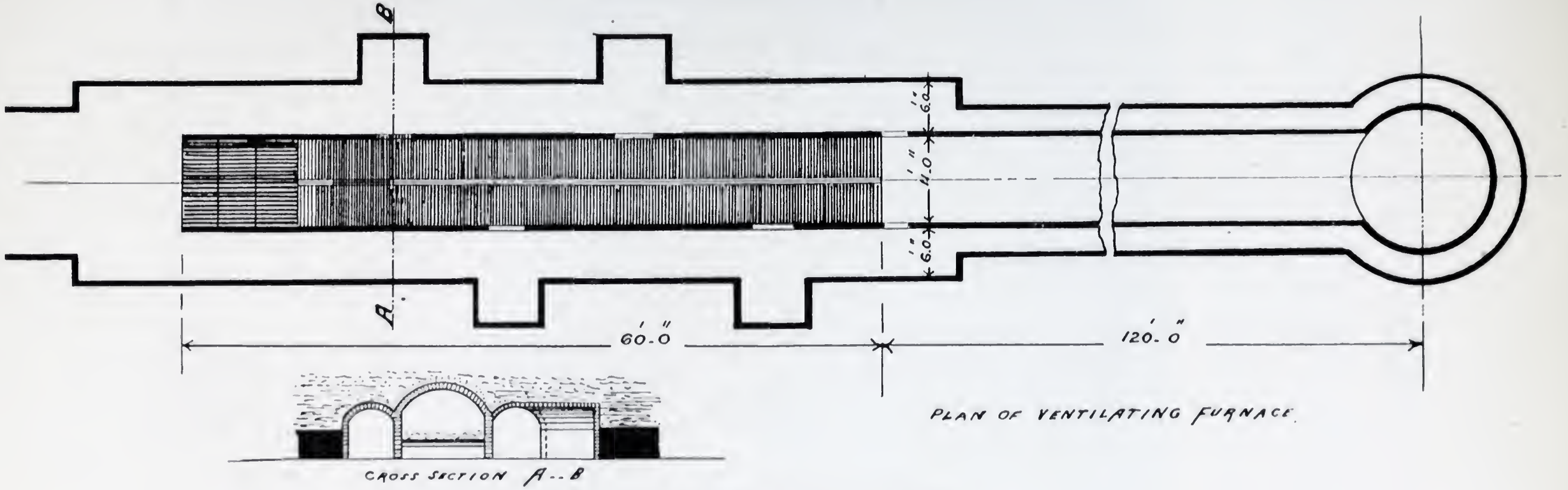
At Rose Bridge, another deep mine in Lancashire still using the furnace, four seams are ventilated, and the volume of air exceeds 200,000 cubic feet per minute, (shaft 810 yards deep). The last time the writer descended this shaft, now over 25 years ago, it was suggested that he accept the loan of a very heavy flannel jacket and turn up the collar to pass the furnace drift mouthings. Afterwards he was thankful for the loan.

In the construction of furnaces, the general plan was to build a central arch for the grate and furnace proper, and two side arches for the purposes of firing and cleaning the rear end of the furnace, which had sometimes 50 feet in length of grate bars by 10 feet wide. These arches were usually backed overhead, next to the strata, with sand. Adjustable iron doors at the front, and a fire brick lined drift to the shaft at the rear, completed the equipment of an ordinary furnace.

The best practice, however, was to throw a large arch over the space intended to enclose the furnace, and build the three interior arches within it as described above. In a furnace so constructed, the writer saw checker work of fire brick over the fire, before he had seen a Siemens furnace, the mine furnaces performing the same functions of conserving heat as does the Siemens furnace, with which you gentlemen are all so familiar.

Two furnaces were often placed side by side, but delivering into a common furnace drift, one being kept white hot while the other was being cleaned.

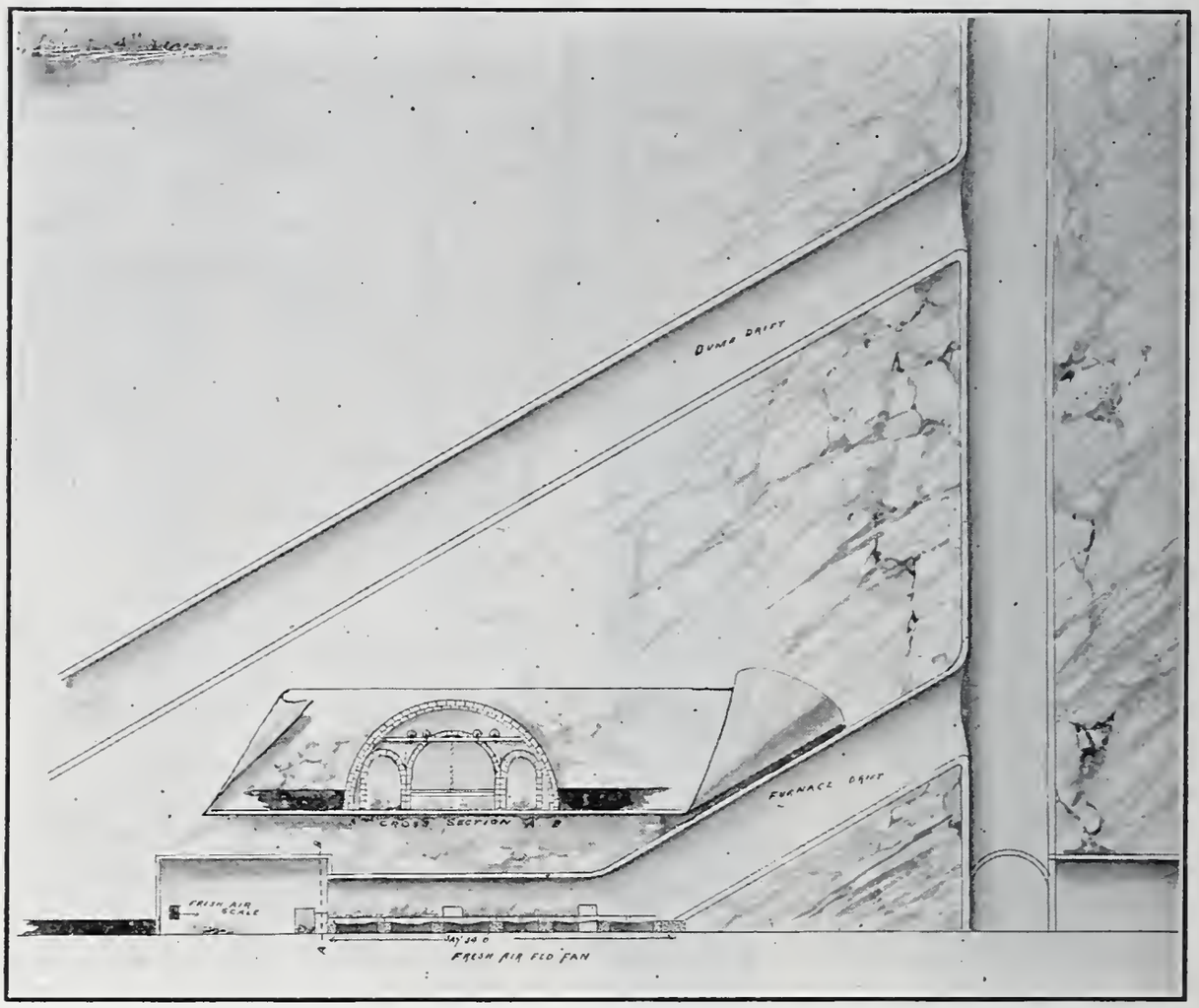
From 1850 to 1860 the mine furnace received its greatest development. In mines where the return air was so highly charged with explosive gas as to render it dangerous to pass the returns over the furnace fire, an arrangement called a "dumb drift" was used. This was an inclined road driven from a point in the rear of the furnace, and in its best form separated



Ventilating furnace for coal mine.

from it by solid strata, entering the shaft at a point sufficiently high above the furnace drift to prevent ignition of the fire damp from the flame of the furnace.

In some pits only part of the air was passed through the dumb drift, and the returns considered safe were passed directly over the furnace fire. The best practice, however, was to feed

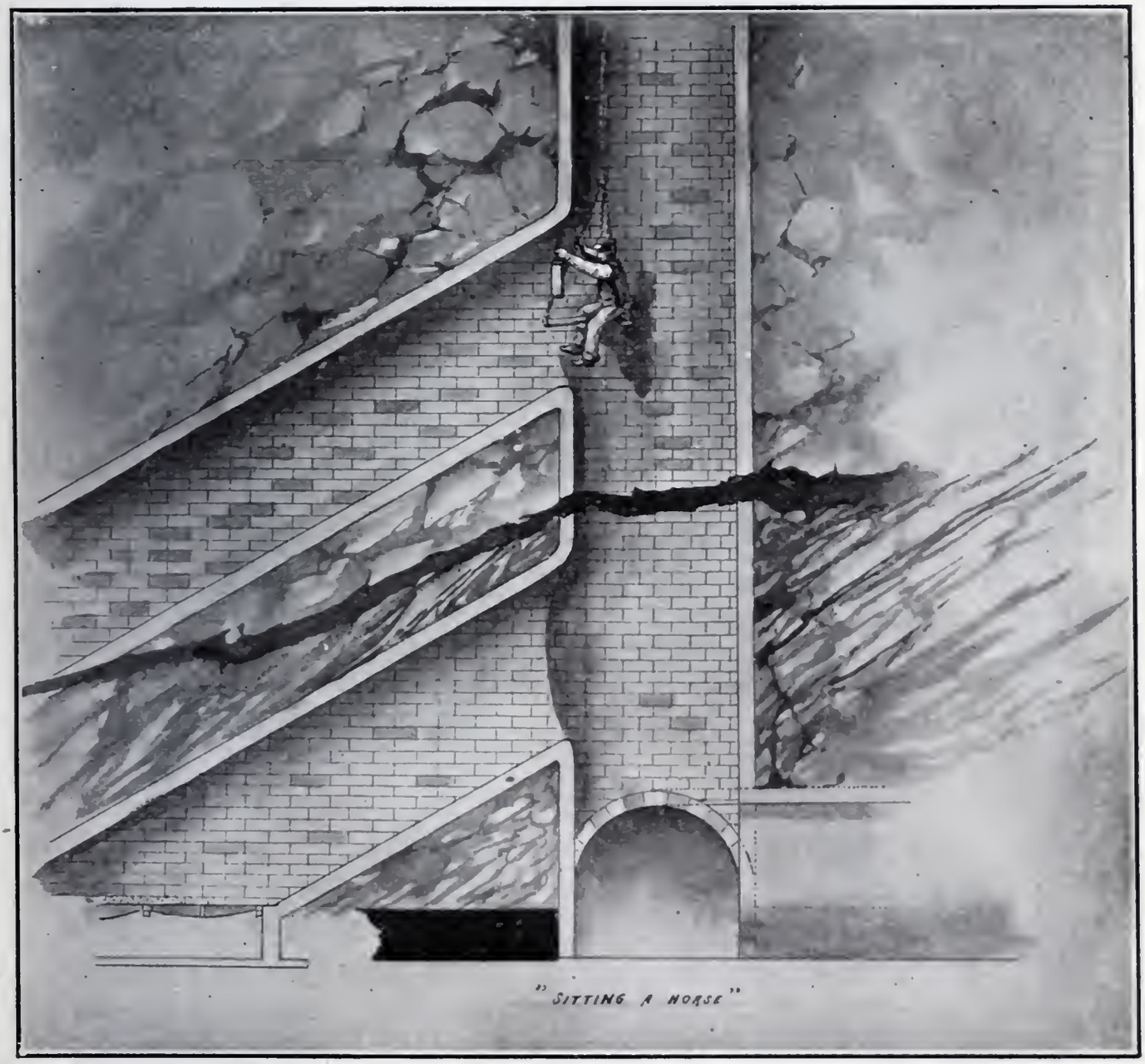


Furnace with "dumb drift."

the furnace with fresh air direct from the bottom of the down cast pit, and pass all returns through the dumb drift.

The danger remaining was the liability to fire soot in the furnace flue below and cause it to blaze out the shaft. This soot was cleaned out during stoppage of the mine, from holidays or other causes, and the writer well remembers doing the somewhat disagreeable duty of "sitting a horse" at the mouth of the dumb drift, watching with a safety lamp for fire damp, while the men were sweeping out the soot from the furnace drift below.

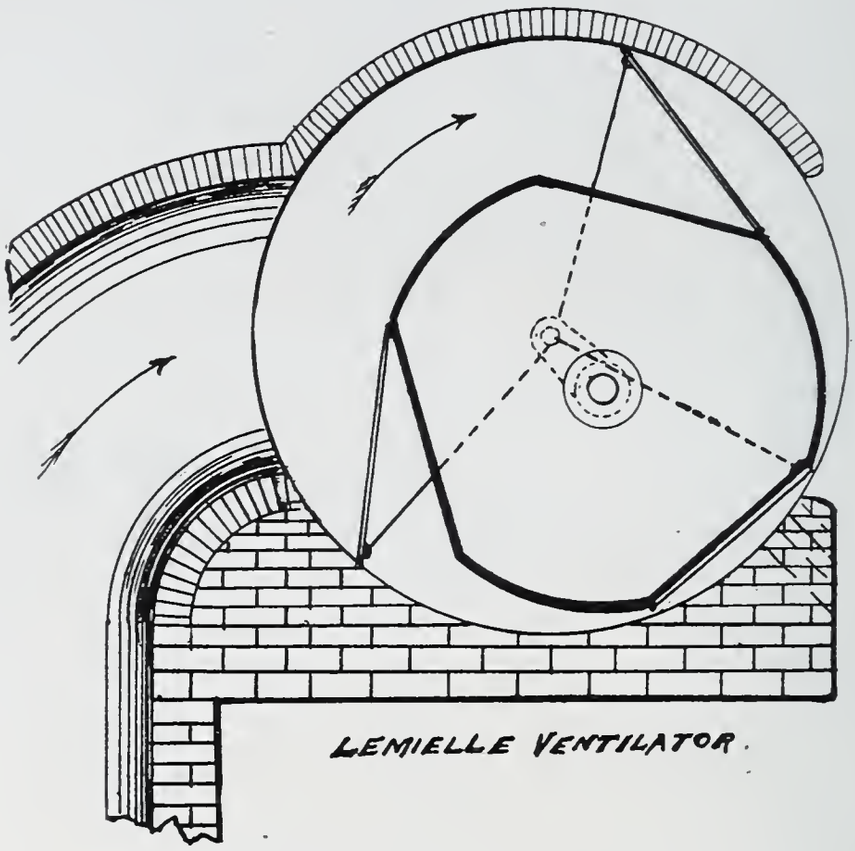
The statistics available, showing coal consumption in furnace ventilation, are not very reliable, as in most cases where furnaces were in use, the up-cast shaft was used as a chimney for underground boilers whose consumption was not generally taken into account. The consumption of coal per H. P. in the



air, varied in every case with the depth of the shaft. For instance, Pelton Colliery, Durham, England, with a depth of 106 yards, the consumption of coal per H. P. per hour in air is given as 69.8 pounds, while at Ryhope, where the shaft is 460 yards deep, the consumption is given as 26.2 pounds.

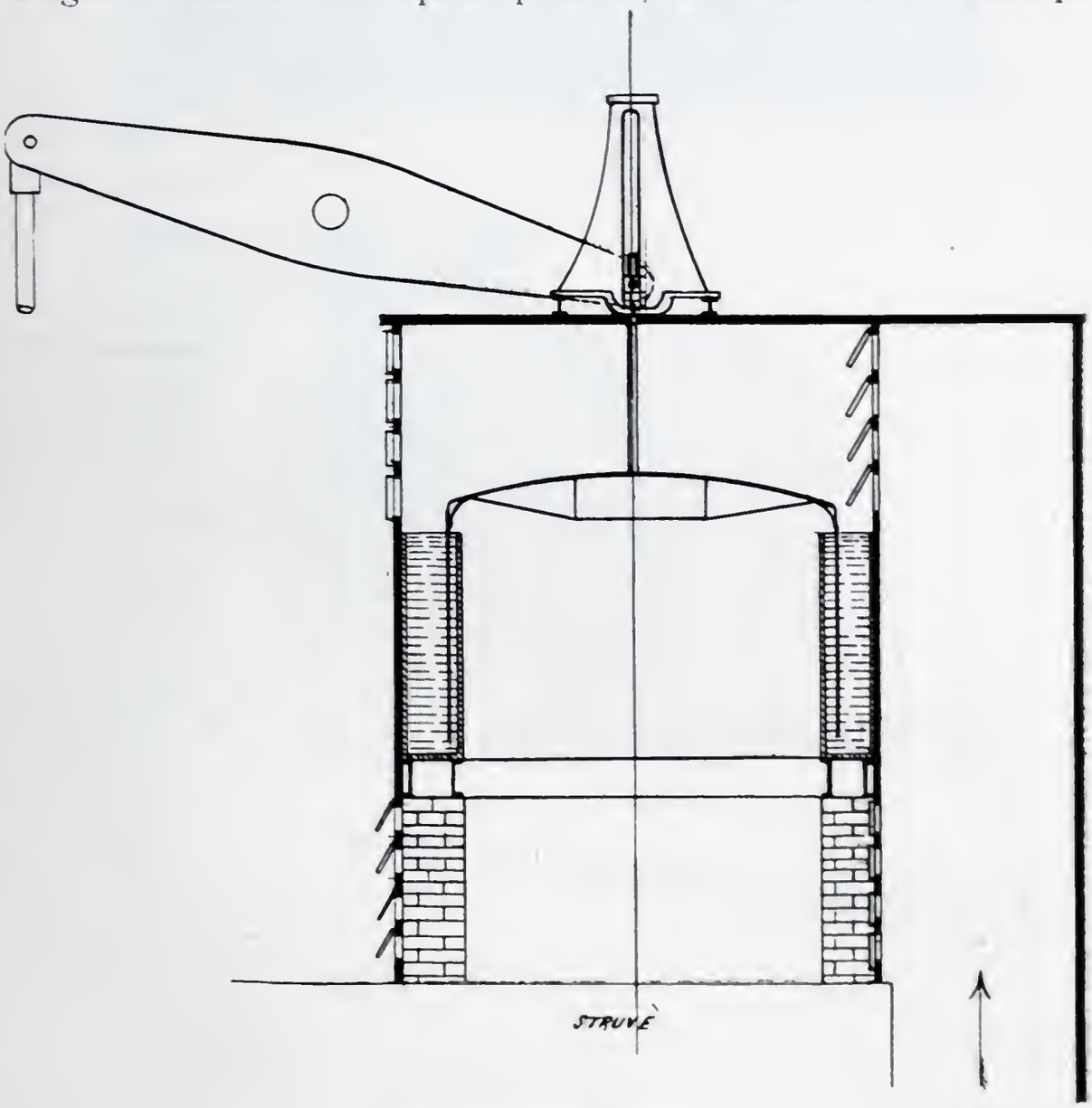
With the best furnaces it was found that coal was burnt very wastefully, and as early as 70 years ago, attempts were made to substitute mechanical for thermal ventilation.

One pet idea was to use the jet like a crude kind of Koerting blower, placed in the mine shaft with its mouth upward. This idea received the endorsement of many eminent mining men and a Royal Commission of the day, but the result was a most dismal failure.



Displacement blowers like Lemeille and Fabry, and the huge piston machines like Struve and Nixon, which though of Belgian origin received their greatest development in South Wales, continued in use until about forty years ago, (indeed the Struve survived much later at Risca, South Wales). But when the chimney and shutter invented by Guibal was placed over a Naysmith fan at Tursdale, it showed that the centrifugal fan was the mine ventilator of the future. This, coming at a time when colliery explosions were so common and sweepingly fatal in Europe, gave the Guibal fan an excellent entry into the confidence of mine owners, and from a European standpoint it has

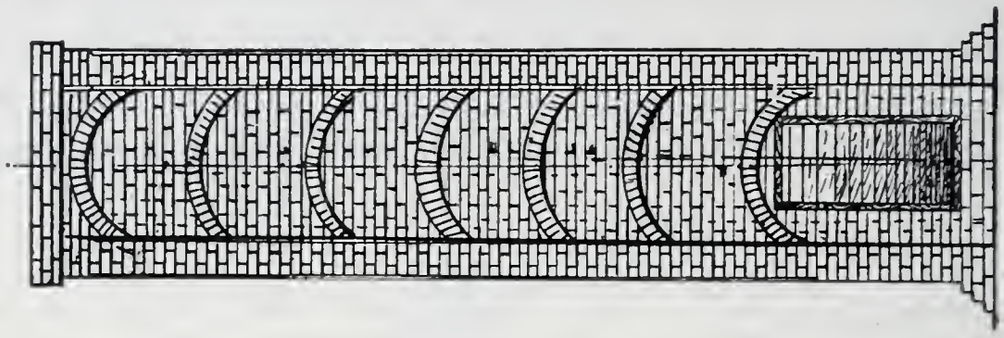
well justified that confidence. The weakness of construction, however, unfavorable to high speed, compelled mining men to stick doggedly and tenaciously to slow running fans. Increased areas, and consequently increased resistance to the passage of air in mines, was met by increased diameter of fans, with a climax of one 50 ft. diameter at St. Hilda Colliery, South Shields, England. Our anthracite friends, in a measure, have sought to emulate European practice, with less success except

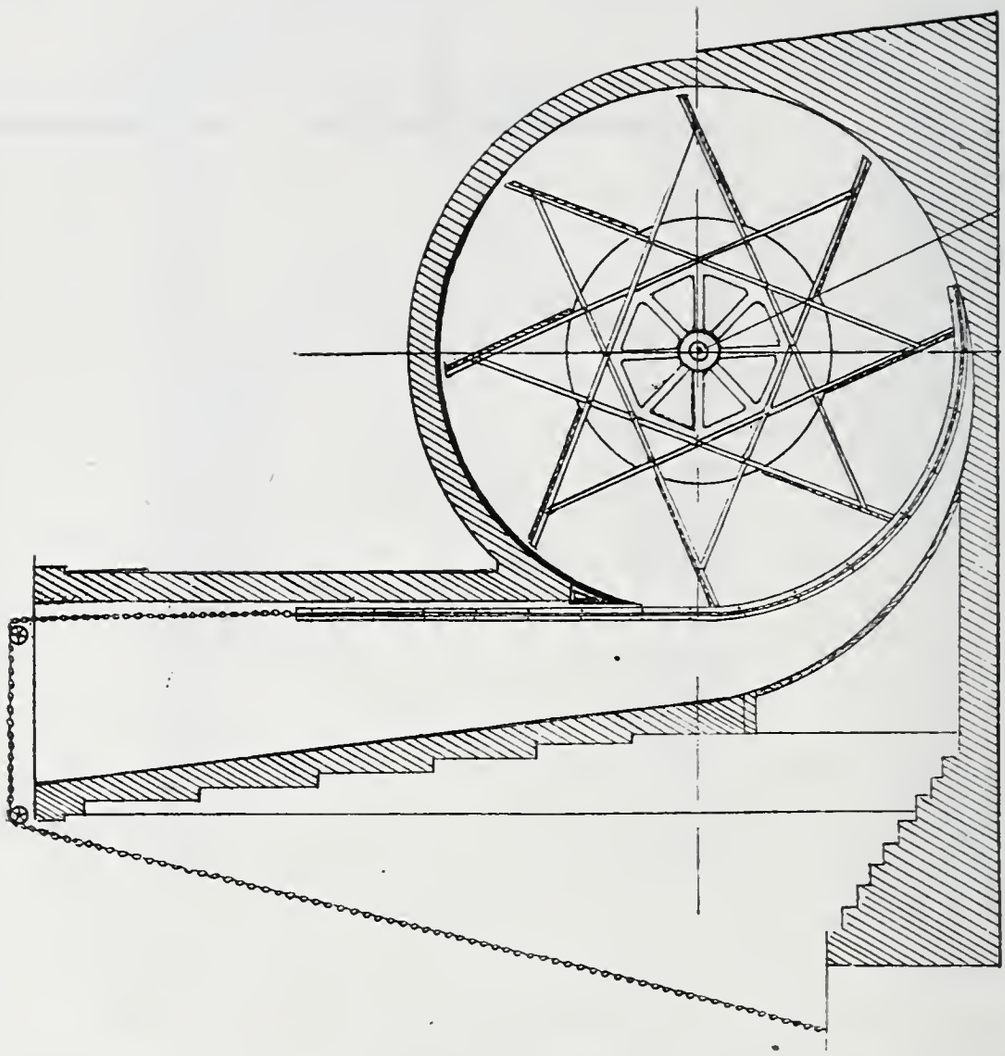


Displacement blower.

in the few cases where Guibal models have been strictly adhered to. But both in England and America, outside the hard coal regions, we have abandoned the idea of getting over the ground with a cart horse, and have decided that a race horse is what we need to win.

The development of electrical machinery has had much to do with the new departure in fans, and the writer would venture to predict that the electric mine fan of the future is one that will be direct coupled to the motor.





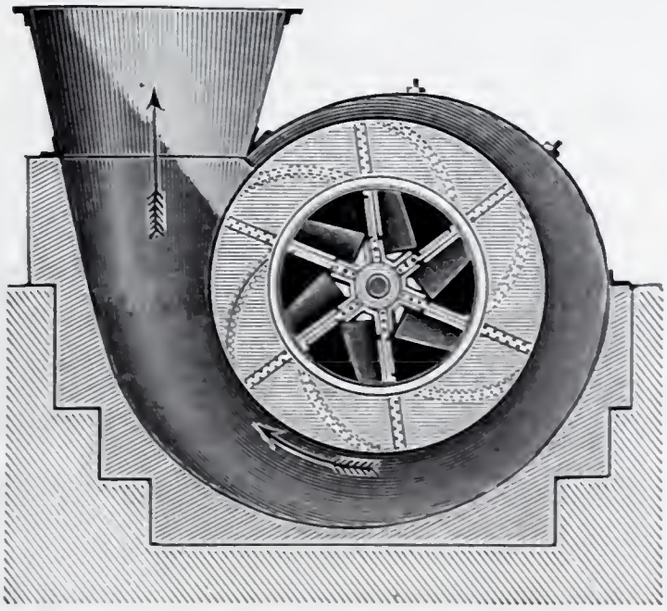
Fan with Guibal chimney and shutter.

In twenty years the speed of fans have increased from about 40 R. P. M. to 200 R. P. M., and diameters diminished from 50 feet, (and very commonly 46 feet) to 16 feet, with results which have surprised even advocates of high speed. A 45 foot Guibal fan at Backworth was replaced by a 13 ft. 6 in.

Capell fan and 50 per cent more air passed at twice the resistance. With fans 16 feet in diameter we have obtained duties which no Guibal fan on earth ever did, or ever could do.

A Clifford-Capell fan 25 feet in diameter, running 128 R. P. M. at the Lambert mine, gave a ventilation of 418,000 cubic feet of air per minute at a mine resistance equal to 6.2 inches of water gauge.

At Briar Hill Mine, Uniontown, Pa., we have passed 462,000 cubic feet of air per minute at a resistance of 6.08 inches water gauge, with a fan 18 feet in diameter, running at 190 R. P. M., with a mechanical efficiency of 79.2% on the indicated horse power of the engine, and the duty could have been steadily maintained.



Capell Fan.

The outlines of ventilation should include some description of the arrangement of underground workings, but the length of the paper forbids more than a passing reference.

The over-cast or air crossing is one of the most important things underground, and its location, size, strength and outlines, are matters for serious consideration of the mining engineers.

About the period referred to as the advent of the Guibal fan, some engineers in England proposed to drive all main air crossings through the solid strata, above or below the road crossed. The writer has personal knowledge of only one mine, (Monk Bretton) where this was done.

When an explosion occurs it has been commonly found that the over-cast is blown down, and consequently the circulation of air cut off from persons within the mine. Where this is the case, after-damp gets in its deadly work on those who have escaped from the heat, or force, of the blast.

In explosions of forty years ago, deaths mainly resulted from after-damp, the force of the explosion having been modified by the lack of air to support combustion.

Very limited observations during twenty years past, and all my reading, lead me to conclude that the great bulk of deaths in colliery explosions during that period are from burning. We do not now get explosions so often, but when we do get them they are usually detonating explosions.

In conclusion the writer ventures to say:

(a) That the air entering a mine should not have a greater velocity than 2,000 feet per minute in the down-cast shaft.

(b) The main airways, from the bottom of the shaft to the first split, should have a combined area equal to 1/3 greater than that of the shaft.

(c) The cross section, at the top and bottom of a fan shaft, should exceed the area of the shaft itself by at least 50%.

(d) Leading curves at the bottom of the shaft are a good thing.

(e) The main splits should be as near the foot of the down-cast pit as possible. Within 100 feet would be good practice.

(f) All air crossings should have cross sections 25% in excess of that of the road delivering into them, and the grade of approach should be kept as low as consistent with practical economy and the volume of air to be passed. This is also true of an under-cast.

(g) In all coal mines, where the working zone is at a distance from the shaft bottom, (or drift mouth) plastered masonry stoppings should be erected in both main intakes and returns, and all air scaled to ventilate old workings should be passed direct into the returns, each panel of gob having its own over-cast.

(h) The initial velocity, at the point of distribution to working places, should be sufficient to allow some scaling without leaving any place in the district dangerously deficient in air.

Where safety lamps are used, the knowledge that the Clanny lamp, bonneted as commonly done in Pennsylvania, is not safe at fifteen feet per second in an explosive atmosphere, should enter into a mine foreman's calculations on splitting.

(i) In working roads and return airways, air should circulate over any cribbing, and when lagging is used, air should invariably be scaled over it.

DISCUSSION.

MR. SAMUEL DIESCHER, Mem. Eng. So. W. Pa.—What gains are there from employing fans instead of the furnace?

MR. F. Z. SCHELLENBERG, Mem. Eng. So. W. Pa.—I understand with shallow working the fan is certainly the best. In deep working the furnace is efficient and in such great mines it is yet doing the work. There is the benefits of the underground heat and of the heated column, but even there the fan is economical, it is contended. In Belgium, on mines a thousand meters deep, the fan is used. The furnace uses more coal and there is the danger from firing the strata.

MR. SAMUEL DIESCHER—Is it not possible to direct the air better with a fan than with furnaces? Is it not of more positive action than the furnace?

MR. WILLIAM CLIFFORD—You have better control of the air with a fan than with a furnace because you can more quickly increase, or diminish, the speed and consequently the volume of air circulating, and with the fan it is generally possible to increase the ventilating pressure beyond the capacity of a furnace of large size even in the deepest shaft mines.

MR. SAMUEL DIESCHER—If we have a mechanical device by which we can bring air to a certain pressure, we can direct the air through flues or tubes to any point we desire, as long as we have the power. With a furnace the energy impelling the air currents cannot well be as high as with the employment of mechanical means, in which case we can give the air almost any velocity, whereas the efficiency of a furnace depends on the

height of the stack, or flue, and the difference of temperatures between the air in the mine and that in the stack.

MR. F. Z. SCHELLENBERG—Is not this high water gauge concomitant with a restricted air passage?

MR. WILLIAM CLIFFORD—Yes, that is what makes the high water gauge.

MR. SAMUEL DIESCHER—Supposing we have a long flue through which we drive air. In order that we can deliver a certain quantity of air at the far end, we make a very wide flue and apply the necessary pressure to overcome the friction, whereas with the furnace, the friction may be so great as to consume nearly all the energy produced by the furnace because the furnace acts by suction.

MR. F. Z. SCHELLENBERG—The furnace acts by the heating of a column of air, and the higher that column is, the greater the motive power.

MR. SAMUEL DIESCHER—It is rarifying the air in the column.

MR. F. Z. SCHELLENBERG—I will take a short cut and say that to my mind the right way to ventilate an ordinary mine is to open up to the fresh air as many places as practical, and draw out at one place with slow speed. You may draw out very slowly if you have a good many fresh air openings.

MR. SAMUEL DIESCHER—There must be a difference in that. The pressure produced must be greater by powerful fans than by a furnace.

MR. WILLIAM CLIFFORD—The furnace is more economical in deep mines than in shallow ones.

MR. SAMUEL DIESCHER—Suppose you make a mine fan as large as there was ever one built, how much of a furnace would it take to produce an equal ventilation?

MR. WILLIAM CLIFFORD—Murton Colliery furnaces probably use as much coal as would be needed to run ten of the largest fans in Pennsylvania.

MR. F. Z. SCHELLENBERG—You see at our depths, that we have here, ordinarily the temperature is about fifty-six degrees

Fahrenheit. That is about the average temperature of the air outside here and is about the temperature of spring water. It is the temperature of our shallow mines when they are ventilated. Of course, if the air is stagnant in the mine, it gets warmer, but the condition we do not have here is of great depths where for every sixty, or eighty, or a hundred feet, another degree Fahrenheit is added and there is greater disposition for ascension. Ascensional ventilation is natural ventilation that we can take advantage of in aid of a machine or a furnace, but with the vicissitudes of the seasons there is baffling and reversing of natural draft. Now in deep Western mines, where explosive gases are not made, it is all natural ventilation.

In the history of this matter, there was a time not very long ago when a mine was run without the use of steam power. Then we built the furnaces as we had no need of steam power for other purposes. Now we are at the stage generally where steam is required, and of course we naturally put in the fan. Besides that, the fan is undoubtedly the best machine for shallow mines, and we are not contemplating any such very deep mines as they have in England.

POTASSIUM PERCARBONATE.*

WILLIAM D. BROWN,
Non-Member.

In the Zeitschrift für Electrochemic for 1897 Emil J. Constram and Arthur von Hansen describe a process for the manufacture of potassium percarbonate by electrolyzing a saturated solution of the carbonate at a temperature below 0° C. They used a porous cell of 200 cc capacity, in which is the cathode solution of moderately strong potassium carbonate and the sheet nickel cathode. The cell is placed in a beaker of such size that the outer space contains 120 cc of the anode solution, in which is the platinum wire spiral, as anode. The whole is immersed in a mixture of ice and common salt which will bring it to a temperature of 15° C. This temperature must be rather closely adhered to. It is of the greatest importance that the anode solution be concentrated. The specific gravity is then 1.556. They also state that the best results are obtained when working with a current density of 60 amperes per square decimeter of anode surface. On any marked variation of the above conditions of temperature, concentration or anode density, potassium bicarbonate is formed instead of the percarbonate. For large quantities they vary the foregoing process by arranging so that a stream of fresh carbonate is being constantly run into the bottom and the floating crystals of percarbonate are forced out of the top of the anode space onto a filter. The crystals are filtered by suction and dried in a stream of dry air. The authors state that toward the end of the drying the temperature may be raised to 40° C without decomposition of the product.

A pure product is obtained by treating the salt with potassium hydroxide in a concentrated solution at 10° C. and washing with alcohol in which percarbonate is insoluble. The

*Meeting of Chemical Section June 22, 1905.

bicarbonate is changed to the carbonate by the hydroxide and goes into solution. By this method the authors obtain a product of 95 to 97% potassium percarbonate, to which they assign the formula, $K_2 C_2 O_6$.

Since the appearance of this article mention has been made of it in various journals. Translations have also appeared. An abstract is found in the Journal of the Society of Chemical Industry, 1897.

F. Mollwo Perkin in the Electro Chemist and Metallurgist and Metallurgical Review of London for 1901 refers to Constram and von Hansen, but modifies the process by using as cathode a lead-pipe through which a common salt solution, at a temperature below 0° C, is made to circulate.

The authors above mentioned state that the compound is an oxidizing agent and gives some reactions. In order to study the compound more fully it was attempted to produce it by the following method. The cathode of nickel gauze was suspended in a porous cup in 150 cc of 20 to 40% potassium carbonate solution; around this was the anode solution of 150 cc of carbonate solution at a specific gravity of 1.556. in which was the anode of platinum wire. This was surrounded by a freezing mixture of ice and common salt.

Following the authors very closely the anode wire was 48 cm long and 0.0345 cm thick, making an anode surface of 0.05 sq. dm. A current of three amperes was used, thus making the density on the anode surface, 60 amperes per sq. dm. But instead of the percarbonate a mass of bicarbonate was formed. This was caused by the rise of temperature: three amperes heated the cathode solution to five or ten degrees above zero, although the anode solution was surrounded by a freezing mixture at 15° C. But by using 1½ amperes and 24 cm. of platinum wire as anode, the anode density being the same, the temperature was kept sufficiently low. The cathode solution did not rise above zero and was generally 5° below. A mass of blue crystals was obtained floating in the anode solution. These were filtered by suction when the blue color almost entirely disappeared.

Potassium percarbonate in solution behaves like hydrogen peroxide. A solution of percarbonate and an alkaline solution of hydrogen peroxide rapidly decompose, and at the same rate; while an acid solution of either does not loose strength on standing open. Moreover, an acid solution of percarbonate bleaches potassium permanganate. The reaction is: $5K_2C_2O_6 + 8H_2SO_4 + 2KMnO_4 = 2MnSO_4 + 6K_2SO_4 + 8H_2O + 10CO_2 + 5O_2$. Accordingly the strength of potassium percarbonate as an oxidizing agent was determined by titrating with permanganate in sulphuric acid solution. This gives the oxygen available. By titrating an aliquot part of the solution with hydrochloric acid (using methyl orange), the amount of potassium is obtained, and by comparing these the percentage of $K_2C_2O_6$ in a mixture of percarbonate and bicarbonate is found. The product obtained in several experiments contained only from 30 to 40% $K_2C_2O_6$, while the authors mentioned state that a product of 80 to 95% $K_2C_2O_6$ is obtained.

Constram and von Hansen state that a concentrated solution of pure potassium carbonate at ordinary temperature will not crystallize out on lowering the temperature, but that an impure salt will. It was found that even a small quantity of sodium chloride caused crystallization to occur on lowering the temperature until a solution of 1.2 specific gravity is reached. At this concentration, ice crystallizes out at 15° C.

The formation of potassium percarbonate at this temperature concentration and anode density is attributed to the separation of K_2CO_3 into K and KCO_3; the KCO_3 to form $K_2C_2O_6$. The high anode density and cathode density are favorable to reactions of this class.

A half pound of potassium percarbonate was received from Eimer and Amend. It had been rebottled by them from an importation of ten pounds. The strength of this salt falls far below the normal. One gram was dissolved in water and aliquot portions titrated in usual manner with hydrochloric and permanganate. From this the percentage of $K_2C_2O_6$ is found to be 39.5.

The salt is relatively stable when kept in the dry state.

Exposed over sodium hydroxide solution in an exiccator for 24 hours five grams lost strength from 39.5 to 13%. In the open air the strength fell in same time to 21%. In a large bell jar, connected with the room by a calcium chloride tube, the strength fell to 35%. It also lost strength at the same rate when powdered and tightly corked in a small vial. The lumps in which it is purchased lose strength less rapidly than when powdered. Also the sample corked lost strength less rapidly than the sample from which we were using.

The similarity of the reactions of the solution of percarbonate and of the solution of hydrogen peroxide has been mentioned. The oxidizing reactions were studied further, a comparison being made with those of sodium peroxide. With a solution of chromium sulphate the sodium peroxide acts quicker than the percarbonate. But the greatest difference is shown in the case of their action on manganese sulphate; the peroxide throws down the black precipitate of manganese dioxide, while percarbonate produces a small quantity of black precipitate, but mostly the white precipitate of manganese carbonate. On addition of sodium hydroxide to this precipitate in suspension the dioxide is immediately formed. With a lead salt the same reactions occur.

From these reactions it would appear that the carbonate is formed, and this is oxidized slowly, if at all, by the available oxygen contained in the solution as hydrogen peroxide. These salts were taken as, perhaps, the hardest to oxidize. The percarbonate readily oxidizes such as ferrous to ferric and stannous to stannic salts. It will also liberate iodine from hydriodic acid solution.

Ordinarily as an oxidizing agent sodium peroxide is to be preferred to potassium percarbonate. Moreover, the price and weight of the compounds are to be taken into account.

If the two compounds showed a strength of 100%, a given amount of available oxygen would be supplied by 2½ times the weight of percarbonate as of peroxide, because of their different molecular weights. As we have it, the peroxide contains 75% of its theoretically available oxygen and the percarbonate but

37½%; therefore in supplying the same amount of available oxygen five grams of percarbonate would be used to one of peroxide.

The retail price of peroxide is about 90c per pound and of percarbonate $2.50 per pound. If both compounds were pure to compete with peroxide, percarbonate must be 36c per pound. The price of percarbonate is undoubtedly high because of its newness and limited use, but could it be made as cheap as peroxide? The percarbonate must, we have seen, be made from chemically pure potassium carbonate as other salts lessen its solubility. The carbonate retails at about 50c per pound, which would fix the price of percarbonate at 70c, not taking into account the labor and energy used to produce the compound; and at 70c per pound in percarbonate, available oxygen is twice the price of that in peroxide.

In conclusion potassium percarbonate can be produced from the pure carbonate, and is an oxidizing agent, but an oxidation reaction that cannot be caused by sodium peroxide remains to be found.

CONSTRUCTION OF COFFER-DAMS.*

BY THOMAS P. ROBERTS,

Member Engineers' Society of Western Pennsylvania.

After your chairman had honored me with the request to prepare some remarks upon the subject of the construction of coffer-dams, I spent some time reading up the authorities as a matter of interest, although the authorities in engineering are generally back numbers and seldom referred to, and herein our profession is vastly ahead of that of the lawyers. I need hardly say that I came across a number of very good plans which had been put in use fully 100 years ago in England, and learned there had been little advance in the methods of framing coffer-dams, so far as wood structures go, in the last 20 or 30 years.

Very deep structures are rarely attempted now-a-days in wood construction, preference being given to pneumatic processes for pier foundations in such cases. As to the limit in depth where the pneumatic system will prove safer and better, much will depend upon the final load expected to be carried, character of material to be penetrated, and to funds available for doing the work. This depth is sometimes taken to be 30 feet, though in the case of the Edward VII. bridge over the Thames at Kew, completed last year, open construction with timber was adopted for depths of 35 feet.

With steel piles on the interlocking system, there is no limit in depth in open construction, where due attention is given to the bracing, excepting the limit imposed by the materials encountered in the driving operations. Their use in many cases will, no doubt, obviate the necessity of resorting to expensive pneumatic processes.

It has not been my fortune to have any experiences so far with steel piling, except to listen to the glowing accounts of the sales agents as they set up their models on my office table. It

*Meeting of Structural Section May 23, 1905.

is really remarkable how rapidly an agent can surround a pile of books, or a "make believe" pier, with his interlocked aluminum or bronze piles.

When I ask them what is to be done if one of the piles strikes a tree trunk twenty feet down in the gravel they reply, "Pound away until you cut right through it." When I suggest a large "nigger head" boulder at the same depth they answer, "That's easy, now here's your ink stand, it's the boulder, when I come to it I start a curve and go right around it, and get on the line on the other side, see, just as slick as a wink." "But suppose," I interject, "it's a nest of big boulders." "Well," they say, "keep on curving around, you'll get through all right."

That's just it, the books and other authorities, including the learned sales agents, know all about the subject of coffer-dams, excepting as to the trifling point of getting them securely in place at the desired depth, so that the engineer in charge can proceed to pump them out and go along with his work. The unfortunate resident engineer can get more advice up to the time he is ready to start work than he can possibly utilize, but when the boulders, tree trunks and quicksands are encountered, and big springs come boiling up through the fissures in the rock, where is that know-all agent? Most likely at that unblessed moment hundreds of miles away setting up his models on somebody's office table.

Here is the part of the science where each engineer must work out his own salvation, or if he seeks advice will probably get the best from the combined knowledge and experience of his derrick man, blacksmith, pump man, pile driver, and dredge runner.

No two jobs are ever alike, the last one being usually the meanest. If it is a leak through a rock fissure beyond the capacity of boiler and pump, the pump man may suggest that in a somewhat similar case he had seen the leak stopped by inserting one or more four inch pipes into the crevices, letting the dam fill up and then running grout down the pipe mixed with very short chopped old rope. The dredge runner may suggest that he had traced the source of leaks outside the dam using a weighted gum ball attached to a cord, feeling "nibbles on his line" as a fisher-

man does—providing, of course, the pumps are working hard enough to develop the requisite "suction" to move the floating ball—and you can then dump the right kind of material on the indicated spot. The blacksmith may insist that ashes deposited around the coffer-dam is the best method, not only to discover leaks but to effectually close them, depositing the ashes from boxes with trigger bottoms, meantime keeping up the pumping and watching for rising particles of ashes inside the dam in order to locate the source of trouble. If the blacksmith hails from Jones & Laughlin or the Carnegie Furnaces, he may say that slag sand is even better than ashes to close leaks, and especially for closing leaks through the coffer-dam structure.

There is a notion very prevalent in Pittsburg that beneath the beds of our rivers there is another large stream, not percolating, but actually running through the gravel overlying the bed rock. On the strength of this idea it has been several times seriously proposed to improve the navigation of the rivers by intercepting the subterranean flow with dikes of concrete sunk to the bed rock from hill to hill across the valleys, the top of the concrete to come only to the level of the bed of the river. I refer to this as a matter of local interest and on account of its bearing on the subject of pumping of coffer-dams in our rivers. Other engineers of the filtration brand accepting the subterranean, or ground water rivers, as certainties have proposed to meet the city's demand for filtered water with wells tapping the subterranean flow.

It is quite natural to suppose that through the usually coarse gravel and boulder beds of the Ohio and Allegheny rivers, where the depth to the rock is often 30 feet, there must be a strong flow of water. It is not generally known, however, that our visible rivers flow over a more or less cemented structure of sand and gravel from two to three feet thick and practically impervious to water. The dredge men and the pile driver men are aware of the existence of this comparatively hard stratum which overlies the softer sands and gravel. So far as I know this "bone bed" extends along the river for several hundred miles below Pittsburg, although it may be absent in occasional areas. At the Ashland, Kentucky, water works where they put down a row of drilled wells near the shore of the river on a line about 500 feet long for

the purpose of reaching filtered water, the impervious gravel was found to be about eight feet thick. Rather curiously the water rose in the pipes, after they had been inserted in the drilled holes, to a height several feet above the level of the water in the river. In this instance the deeper gravel was surcharged by hard limestone springs. Large springs have been struck in the river bed at several places within our city limits.

That the subterranean discharge beneath the river beds about Pittsburg is exceedingly small has been conclusively demonstrated by the operations of the United States Engineers in the construction of locks and dams. The Allegheny river below Herrs Island, foot of 20th St., Pittsburg, was, during the construction of the dam at that point, penned off with dams from shore to shore in three sections, one section at a time as a matter of course. After each of these coffer-dams was settled and made reasonably water-tight with inner and outer embankments, a twelve-inch pump would keep any one of them dry. Excavations were made in them to the depth of about 15 feet below the bed of the river, the excavation in no case adding materially to the volume of water which had to be pumped. The sections unwatered covered from 2 to 3 acres each. It is thought by Mr. J. W. Arras, the engineer in charge, that fully two-thirds of the water pumped in each section came either through the coffer-dams or directly beneath their bottoms where they rested on the hard bed of the river. In other words a 12-inch pump would take care of the ground flow of the Allegheny river.

At Lock No. 2 on the Monongahela river where we have a similar dam enclosing 3.4 acres, and in which we have excavated 7 to 8 feet below the original river bed, a ten-inch pump keeps the water out easily. There is not the slightest doubt that at No. 2, but for filtration through the dam proper above the level of the river bed, that a two-inch pump would take care of the ground flow or discharge beneath the river bed for one-quarter of the river's width. In our work, on 250 feet of the foundation for the dam, there was no appearance whatever of water rising from the bottom, a small syphon being able to pump out a trench 50 feet wide, 250 feet long, excavated 6 to 8 feet below the bed of the river. Excavation can be done in such large dams

about as easily and as cheaply as on dry land—locomotives and dump cars running on dry road beds within them. Precisely the same experience was had at Davis Island on the Ohio, and at other dams below it where extensive areas were pumped out, and excavations made beneath the river bed. Occasionally small springs are struck in the dams and I know of many places where the geological synclines cross the river, where numerous large springs occur in the river bed, but so far the government engineers have been lucky enough to miss such places and can always miss them if they look for the signs of their presence.

It would only be possible therefore to obtain so-called filtered water in large volumes direct from the river, by breaking through the hard pan crust of their beds, and depositing loose sand and gravel over the filter conduits, and this filling, I am persuaded by experience in dredging along the rivers, would become cemented by the lime and silica carried in the river water, so as to become practically impervious to water in 3 to 5 years.

With this explanation you will cease to wonder at the economical and simple construction of the coffer-dams used hereabouts on river work where large areas must be unwatered. These dams cost from 8 to 10 dollars per running foot and are usually 10 to 12 feet wide, 14 to 16 feet high, covered on top. The bottom wales are 10 inches square, the middle one 8 inches, and the top wale about 6 inches square. Two inch hemlock sheeting is used driven with mauls usually not more than a few inches into the hard river bed.

So far as the coffer-dam at No. 2 on the Monongahela, opposite the Carnegie Steel works is concerned, the river gravel used for filling and banking it inside and out, would of itself have made an impervious dam, but the timber form in the heart of the bank is necessary because of the floods which would otherwise wash the bank away.

At No. 2, there is an admixture of clay with the sand and gravel, as brought up by the dredges, of about 1 clay to 2 sand, and 6 gravel. Now if we substitute cement for the clay we have our average concrete mixture, and therefore the aggregate of our embankments ought to be as water tight as concrete, and so, no doubt, it would be if it had been systematically deposited so as

to allow none of the clay to wash out. Clay, be it remembered, is more finely ground than cement.

This brings up the subject of materials for filling coffer-dams. There is such a case as having too much of a good thing. The good thing is clay but it should not be in excess. Clean sand alone is preferable to pure clay alone for filling coffer-dams. The trouble to be avoided is having the clay so strong that the smallest leak through it may rapidly develop into a self-arched tunnel.

When I recall some railroad pier coffer-dams that I put in years ago, I would, if I had the jobs to do over again, advise myself as follows: Before shovelling into the dams any sand mixed with clay to endeavor first to sink a course of water logged chopped oat straw, by dropping ashes over it, or forcing the straw down with a wire net and filling the straw with ashes, or slag sand, to the depth of several inches. The first and generally the only thing needed to make a tight dam is to put some material in its bottom, which when a fluid pressure is exerted upon it will tend to choke up the outlet.

On bridge work it is seldom that it would be practicable to place the dam at distances of 50 to 100 feet from point of maximum depth of excavation, as we like to do on the river. The streams are too narrow and besides they may not have the impervious "bone beds" as the dredge men call the hard stratum of our river beds. Hence it comes that the dams are close to the masonry line. In lieu of inside embankments, however, the bridge engineer has better and safer methods of bracing his work to resist heavy pressures than we have on our dams. To secure a good job the sheet piling must be very carefully driven. It is better to lose a half day's time pulling out a stick which has wandered, and putting in its place a stronger one, probably with an iron shoe on it. Whenever possible the piles should pass between two lines of waling or guides, the guides as far apart vertically as practicable and every pile, while being driven, kept tightly clamped with a chain to those already in place. Care and patience count more than anything else with sheet pile driving.

I will remark in conclusion that steam pile drivers are much

to be preferred to drop hammers. A pile which goes down with a uniform speed is less apt to jam, buckle, or split than when driven with heavier blows with marked intervals of time between blows. I base this statement on what I have observed in putting down steel testing rods by hand. Thus through soft gravel mixed with quicksand a man may be able to push a rod down five or six feet and if quick enough with the same expenditure of power pull the rod up again. If, however, the rod is left to stand, even no longer than 15 seconds, the sand packs against it so that two men may scarcely be able to pull it up. A pile therefore left standing in some kind of sand for a few moments may become so packed as to refuse to be driven further, or at least require much greater force to be started again. This packing of sand about piles impresses me with the belief that we may often underestimate their stability and the loads they might safely carry.

In conclusion I will remark that in one treatise on coffer-dams that fell under my observation it was said that the engineer should regard them as retaining walls and calculate for their overturning moment accordingly. I think this remark should have been qualified to read that a coffer-dam is like a retaining wall, only one is begun at the top and the other at the bottom. The engineer must stand on his head, so to speak, to fully comprehend the similarity of the two kinds of structures. If even some of the best designed retaining walls commenced at their bottom on dry ground, or rock, upset occasionally or slide on their bases, there ought to be more excuse for the engineer who begins to build his up side down retaining wall, or coffer-dam, at the top, while to a great extent ignorant of what is going to be found as his work proceeds, if said work takes a notion to burst in while it is being pumped.

DISCUSSION.

Mr. Robert A. Cummings, Mem. Eng. So. W. Pa.—The purpose of a coffer-dam, as we all know, is to keep out water. Mr. Roberts has given us an admirable description of the coffer-dams used in the government service. As a contractor for some of that work, I may supplement it by one or two remarks. In

1901 I entered into a contract with the United States to rebuild the upper guide wall at Davis Island Dam. This guide wall was originally an old crib. The coffer-dam for our work was precisely similar to the one referred to by Mr. Roberts, but it was to be built within three feet of the work. One of the conditions was that there should be no banking on the outside of the coffer, and obviously it could not be done on the inside because it was only three feet from the wall. We were permitted to place a small quantity of material on the outside, but it was found that it would wash into the valves of the lock chamber down stream from us and it had to be abandoned, so we had practically no protection on the outside of our coffer, which was built upon indurated gravel and on rock. We could not drive our sheeting into that, with the result that we were unable to unwater the coffer-dam, which was about 700 feet long. We had to resort to special means, that is, by cutting off sections of about 200 feet, then putting three 12-inch centrifugal pumps to keep down—not keep out—the water. I can't say this coffer-dam was a success from a contractor's standpoint.

Mr. T. P. Roberts—Did you put any straw on the bottom?

Mr. R. A. Cummings—Our specifications did not permit straw and as a Government contractor, we would necessarily carry out the contract in accordance with specifications. I have mentioned that as a place where this design of coffer-dam should have been modified.

Mr. Francis Donaldson, Mem. Eng. So. W. Pa.—On the Big Sandy work for the Cincinnati office last year they had a coffer-dam built close up against the work and they specified three-inch tongued and grooved yellow pine sheeting.

Mr. R. A. Cummings—The conditions at Cincinnati and the Big Sandy are very different from what you meet around Pittsburg. The bottom of the Ohio river near Pittsburg is indurated gravel; at Cincinnati it is a particularly loose material.

Mr. E. K. Morse, Mem. Eng. So. W. Pa.—What would you suggest?

Mr. R. A. Cummings—I would probably have adopted some such means as Mr. Roberts has suggested, by putting stiff

sandy clay on the river bottom in which to drive the hemlock sheeting.

I also built under specifications from the United States the coffer-dam for Dam No. 5, at Freedom, Pa. So far as I know, that was the first coffer-dam constructed on the Ohio river that differed from the characteristic Pittsburg skeleton coffer construction. It was built of piles, six feet, center to center, with waling pieces on the inside to which 2-inch hemlock sheeting was to be attached, and hemlock is not very desirable to drive on a hard bottom. There is one feature about the building of that coffer which I wish to point out, and that is that the piles were driven butt down. There were about 600 piles in this coffer-dam and we were much concerned about our ability to drive them butt down. We asked permission of the resident engineer to drive them in the usual way, but he said the specifications called for them butt down and we would have to follow specifications. However, we were permitted to try a few in the customary way and were very glad to get back to the method of driving butt down.

The only explanation which I can offer is, that, as the average oak pile is tapering it acts as a wedge. The force of the hammer blow is transmitted through the pile and is resolved into horizontal and vertical components, the horizontal component of the force acting normal to the surface of the pile and the vertical component on the point. That is sufficient to make it very hard driving. Reverse the pile, and in driving you have no horizontal component to take care of, all the force of the blow being transmitted to the point, and as a result it goes a great deal easier.

Mr. W. G. Wilkins, Mem. Eng. So. W. Pa.—How do they pull out?

Mr. R. A. Cummings—In our attempt to pull them out, we broke up all the blocks and falls we had on hand and finally the government engineers permitted us to cut them off below sill level of the dam.

We drove some of those piles 20 feet below the bed of the river and I don't believe we drove any of them less than ten or twelve feet. We used a 3,600 lb. hammer. We banked the coffer on the outside and filled in the inside with dredged ma-

terial, sand and gravel. The upper and lower arms of the coffer-dam being only about 155 feet apart, no doubt was one of the causes leading to the scouring out of the lower arm which occurred in the following winter. This coffer-dam retained a head of water within three or four feet of the top without serious trouble, no break occurring in the coffer. The leakage was very largely from the outer arm and springs in the bottom of the river or water coming through under the adjacent lock walls.

In regard to the river work, these coffer-dams are successful and the cheapest and most economical form of construction.

There is one other coffer I wish to call attention to and that is the crib coffer-dam. From a contractor's standpoint they are economical where you have plenty of wood to draw your supply of logs from, and they are very easily constructed. The material for use in coffer-dams is confined to a choice from the local supply. Anything that will obstruct or impede the flow of water most efficiently will be the best. Sand and gravel mixed with mud, clay or loam to fill the voids should be used for filling in preference to clay alone. A leak forming in clay will continually enlarge its hole and expand in size the more you pump until the capacity of your pumps is exceeded. But this is not the case with sand and gravel which fall in and automatically fill up the hole causing the leak.

Mr. John M. Rice, Mem. Eng. So. W. Pa.—What is considered the maximum depth of skeleton coffer-dam construction of the type described by Mr. Roberts?

Mr. T. P. Roberts—The plan has been used by the government for twelve or fifteen feet only. But with a dam sufficiently far away from your work to carry down the inside bank slope of one to two, excavation might safely proceed to any desired depth below pool level.

In regard to Mr. Cummings' explanation of driving piles butt end down, I think he is correct. Only I believe that pile will not sustain as heavy a load as the pile driven as a wedge.

In the paper I tried to emphasize the importance of putting ashes or straw in the bottom before the sand filling is put in. It is hard to get straw down in the water unless it is sunk with a wire screen, then put the ashes on that. If Mr. Cummings

had done something like that at Davis Island he would not have had the trouble with leaks. The leaks are nearly always at the bed of the river at the bottom of the coffer-dam. I have had dams in the Monongahela river in ten feet of water, with seams in the rock at the bottom, that we choked up in this way and had no leakage whatever.

Mr. R. A. Cummings—At Dam No. 5, our foundation went down about 14 feet or more below the bed of the river and we had at that point a maximum of 24 feet head of water. This water was within 50 feet of the face of the foundation. With that head there was no blowing of the sand or gravel in the bed of the river, but the leakage increased immensely. At one time we pumped leakage to the amount of fifty million gallons of water in 24 hours. We measured it over a weir and then checked that measurement by the mechanical efficiency of our pumps.

Mr. John M. Rice—Are you troubled with the material in that kind of a dam freezing when the water is low, and forcing out piling?

Mr. T. P. Roberts—Dams are frozen every winter. They are very flexible, however, and they will take care of themselves. Some of them in the Ohio have been alternately frozen and thawed out repeatedly and are still serviceable.

Mr. John M. Rice—I have in mind a dam of that nature at Dick's Lake, Minn. It was very tight after being built, but during the winter the enclosure was allowed to fill up and when it was pumped out the following spring several bad leaks developed. It was claimed that these leaks were caused by the filling between the walls of the coffer-dam freezing and expanding, breaking the tie rods and forcing the sheet piling apart.

Mr. E. K. Morse, Mem. Eng. So. W. Pa.—In 1897 I designed and superintended the construction of the substructure of the Port Perry double tracked hot metal bridge for the Union Railroad, which is located not over a quarter of a mile above Dam No. 2 in the Monongahela river. There were seven piers in all. Pier No. 1 was at the edge of the river on the right bank and No. 7 on the beach someways back from the line of water, Pool Full, on the left bank. The foundation of Pier No. 1 was

shale, and piers 2, 3, 4, 5 and 6 were on pile foundations, which were first dredged out and the piles then driven and cut off about 16 feet below Pool Full. The average cut-off for the piles in the river foundations was not over 12 feet, as it was impossible to drive into the hard pan gravel more than two to six feet, but which seemed to soften, however, as we approached the left bank until close to the left hand shore, the old channel was met with and piles were driven considerably deeper before the hard pan gravel was met with. It was the original intention to excavate the foundations for the river piers, but after considerable time and money was spent on Pier No. 4, the balance of the river piers were dredged, piles were driven, cut off, and the foundations landed in the ordinary method for caisson construction. Pier No. 7, which was in fact on dry land during its whole construction, was sheet piled and excavation started, but after reaching an elevation about six feet below Pool Full, the soft, bluish, black clay suddenly seemed to assume the characteristics of a quicksand and without the slightest warning, the water would boil up and form a mound three or four feet high, when it would suddenly shut itself off and break out at another point. This proved so annoying and the foundation softened to such an extent, it was finally divided off into sections and these in turn were removed and the piles driven butt end foremost to the hard pan, some 30 feet below Pool Full. This packed the bottom of the foundation and by dividing up the foundation into small sections the excavation was finally carried down to a sufficient depth, piles cut off and concreted and another section started. After the last section was completed, the inside partitions were removed and the whole thoroughly concreted and firmly joined together. I am satisfied that the contour of the river at this point is different from that at Lock No. 2, which is below the mouth of Turtle Creek, but I am firmly of the opinion that if the cribbing for this foundation had been set back sufficiently there would have been no trouble in the filtration through the bottom and the head of water would have been cut off.

Much the same experience was met with in putting in the foundations for the Bessemer Railroad, at Denny, across the Allegheny river and in this case a pier which was located back from

the top of the bank, in a corn field, developed the most trying conditions and almost assumed the proportions of a quicksand foundation, although a pier in the river only a few hundred feet away rests on hard pan gravel foundation. It is 98 feet high and has never settled nor listed.

I have never put in a pier on the river edge of the Allegheny or Monongahela, except where rock has been obtained, that has not given more trouble than all the rest of the piers together, and so uniformly has this been the case that I design, where possible, to eliminate all piers near the water's edge or partly on the bank. The main trouble that a contractor has in the first stages of construction is the inability to shore up and brace sufficiently against the bank, which failure often is the cause of the contractor's losing possession of the work and the bank begins to crack up and creep, which when started often reaches alarming proportions.

Mr. Francis Donaldson—At Lock No. 2, last summer when the river was very low, the water was extremely acid. We changed the supply pump from the outside, in the river, to the inside of the coffer-dam and the water was not only not acid but we had it analyzed and it was slightly alkali. How could filtering through a coffer-dam take out free acid?

Mr. T. P. Roberts—You could not filter the acid out of the river water.

Mr. E. K. Morse—It was the undercurrent. You go up the Allegheny river ten or fifteen miles and the conditions are different. There is a very strong undercurrent. You cannot put a filter under the Allegheny river anywhere near here. It has been tried and has always been abandoned.

Mr. R. A. Cummings—It is possible that the alkalinity of the water was due to the cement in the concrete work which was going on inside.

Mr. E. K. Morse—A fine illustration of the underflow was at Mingo some years ago. They dredged a channel from one bank of the river to the other, and even back at the upper end the water flowed nearly as fast as out in the river. Apparently more water flowed through the gravel than out in the channel.

Mr. W. C. Hawley, Mem. Eng. So. W. Pa.—One of the best illustrations of that which I have ever known, occurred at Peoria, Ill. Some years ago, in building the water works there, explorations were made to locate such an underground current of water. Following up the valley about five miles, we located a stratum of gravel, through which there was a very free flow. At one point about three miles above the city, we put down a six-inch pipe off a bridge pier in the river, and the water in that pipe rose to a point about seven inches below the level of the water in the river. Chemical analysis showed it to be entirely different from the water in the river. About five hundred feet back from that well, on the shore, we put in a large open test well. When the test well was pumped, the water in the pipe in the river was lowered several inches; but as soon as the pump stopped, the water came back immediately to its original level. In dry weather, the water in the Illinois river went down several feet, but the water in this pipe remained at practically the original elevation during that time. The city has for years been securing water from this underground source, entirely independent of the Illinois river.

Speaking of driving piles, and the earth settling back around them, holding them in position. Many of you have seen them driving piles at Atlantic City, where they use a jet without attempting to use a hammer. The first time they tried to drive piles, fifteen or twenty years ago, a Philadelphia contractor "went broke" trying to drive piles in that sand which, when wet, is almost a quicksand. Now, a contractor thinks nothing of putting in 100 to 120 piles in a forenoon with a jet. They simply put a nozzle down in the sand, and the sand is washed up, so that in a few seconds they have a hole ten or twelve feet deep. The pile is lifted with a block and fall on a tripod and dropped into the hole. They shovel sand around it, and in a few seconds more, it is in so there is no way to pull it out except to wash it out with a jet again.

CONCRETE LINING FOR MINE SHAFTS.*

BY F. R. DRAVO,
Member Engineers' Society of Western Pennsylvania.

The increased cost of timber and inferior quality commercially obtainable have made some other kind of shaft lining desirable in operations where, by reason of the extent of the workings, the life of the mine would outlast the timber lining. The decreased cost of cement has added to the weight of the argument in favor of concrete. The incidental advantages of safety from mine fires and shutting off of water in the shaft will be touched upon later.

Other materials than concrete have been tried and found wanting by reason of the increased cost in case of brick or stone, and where they have been used, even with the best workmanship, they have been found to be exceedingly pervious to water and in cold weather, owing to their roughness, help the formation of icicles to the great danger of the shaft and machinery and pipes therein. The excessive cost of brick or stone linings in this vicinity is on account of the original cost of materials, the necessity of using an excessive amount of mortar, and the high cost of skilled labor to place such linings under the adverse conditions usually found in a mining shaft. Then again, the time required to place brick or stone adds at least double the time required in lining with concrete and when the job is finished, it is not so strong by reason of the difficulty in securing a bond to the walls of the shaft, which indeed is almost impossible in the presence of an ordinary amount of water, while with concrete the presence of water in ordinary quantities presents no difficulties and adds little to the cost. Of course, where water is encountered in great quantities, concentrated in a shallow stratum, the usual water ring must be provided for in any event.

*Meeting of Structural Section April 25, 1905.

The usual timber lining lasts from twelve to fifteen years and in from six to eight years it becomes necessary to replace individual timbers and sections of lining, causing temporary shut-downs at times usually inconvenient, because not done until absolutely necessary; and while the original lining and timbering may be executed in the best manner as regards design, workmanship, and materials, the continuing repairs are almost always of the most make-shift and haphazard character. In the life of a mine of any considerable size, say thirty years, it will be necessary to re-timber the shaft entirely at least once beside making many minor repairs. To re-timber a shaft usually requires a complete shut-down of the mine while the work is being done. A fair comparison of the relative costs of timber and concrete linings will, therefore, take into account this additional timbering. The cost of this, owing to the removal of the old lining and the increasing price of timber, and probably labor, will be much higher than the cost of the original lining, and to this direct cost must be added the loss of income from the mine during the time of repairs.

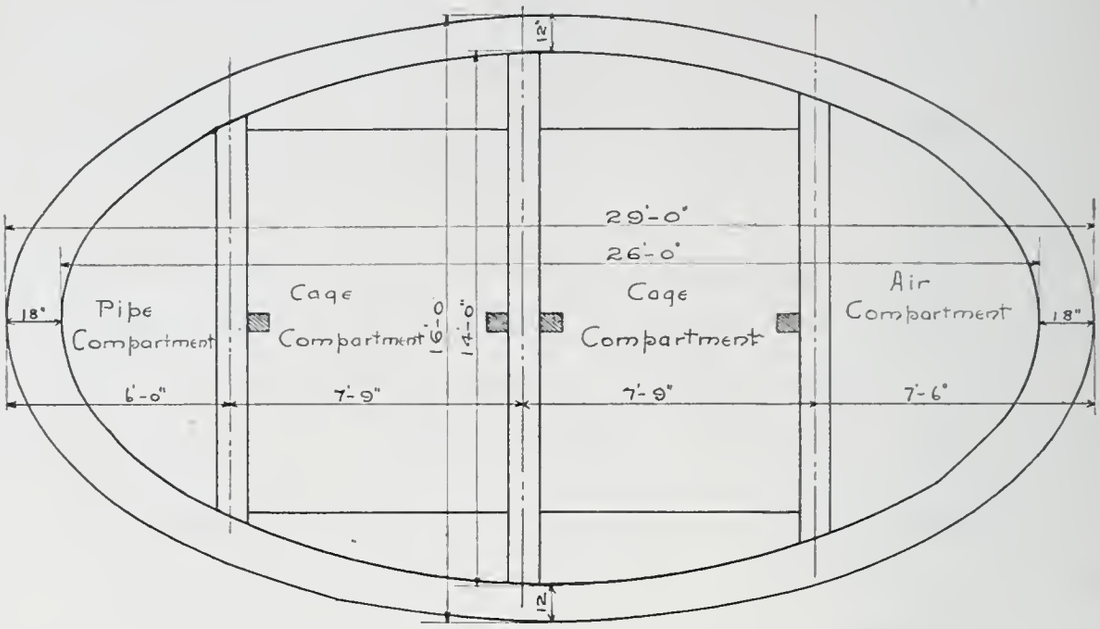
Another disadvantage with wooden lining and timbers is the danger from fire from any cause such as an explosion in the mine or from lamps, electric wires, or stoves at the foot of the shaft. Frequently in the case of an explosion where fire in the shaft does not ensue, the timber is more or less badly wrecked and the resumption of work delayed. Where fire does occur in the shaft, it is usually ruined and causes an increased cost of repair, which would put down an entirely new shaft. This increased cost of repair is due to the necessity of trimming out the rock and shale that have been spawled, cracked, or otherwise injured, due to the heat. No shutting off of water is possible with a timber lining, and owing to the projection of the buntons and timber sets, the water finally reaches the bottom of the shaft in a perfect rain unless provided for by an additional interior lining which of itself adds to the cost, interest and depreciation, making inspection impossible and repair difficult and expensive. On this account interior linings to provide against the dripping of water are seldom used. In the case of downcast air shafts, this dripping rain of water becomes so annoying and dangerous in freezing weather that an interior lining must be provided nevertheless.

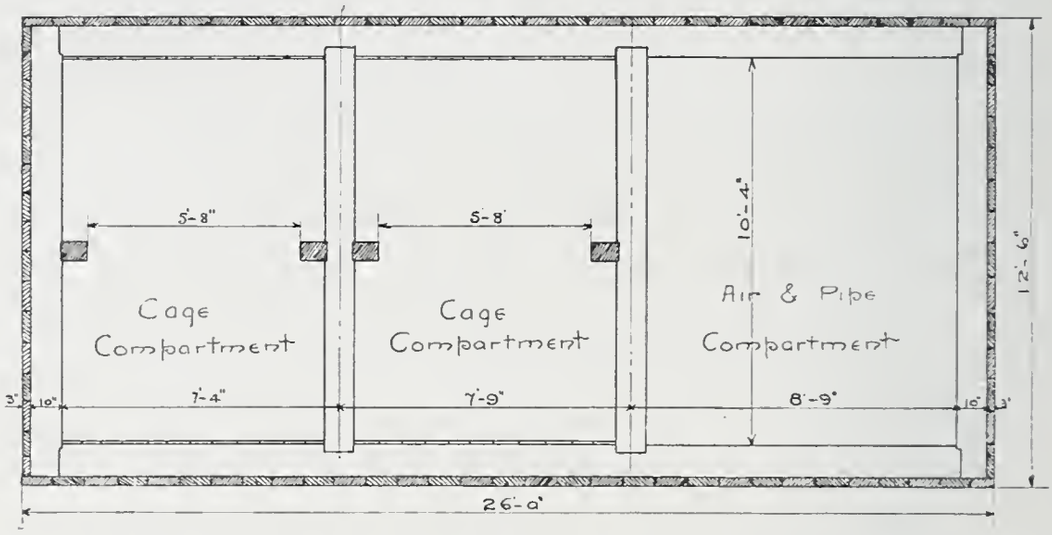
The projection of the timber-sets into the shaft is a source of constant menace that has frequently proven serious, not only to the property, but to human life as well. The placing of a car or the projection beyond the limits of the cage of any object carried on the cage is almost sure to strike one of the shaft timbers and cause a disastrous wreck, or, if only the breaking of the hoisting rope, the results are bad enough from the standpoint of cost.

The only advantage in favor of timber lining is the lower first cost, the greater speed in placing this lining, and the fact that timber is better adapted to the rectangular or square plan of shaft called for by the elevator cages. The cost of timber lining depends, of course, on the locality, but for Western Pennsylvania, Ohio and West Virginia, it may be depended on to cost about $22.00 to $26.00 per thousand feet B. M. for desirable grades and kinds of timber. The framing and placing will cost from $25.00 to $30.00 per thousand feet B. M. As a matter of construction the timber lining can be placed in about one-third the time required for concrete, which would amount to a gain of thirteen days per hundred feet of shaft of ordinary size, a matter of small importance when considered alone.

When it has been decided to use a masonry or even cast iron lining, considerations of strength make it desirable to use an elliptical or circular section, or, in other words, by the use of a circular or elliptical section, a large amount of concrete and consequently excavation can be saved; although on the other hand the elliptical form causes some increase in addition to the area required to accommodate the elevator cages. The end spaces of the ellipse may be utilized for pipe ways and wire conduits, while the spaces on the sides are usually waste room. Roughly speaking, a rectangular shaft lined with concrete would require walls twice as thick as an elliptical shaft which would increase the excavation correspondingly and therefore the cost, while the concrete would cost almost twice as much. A comparison of a hoisting shaft and an air shaft of the usual design and with timber lining with corresponding elliptical and circular concrete lined shafts will present an example which will closely approximate the conditions obtainable in this mining region, and

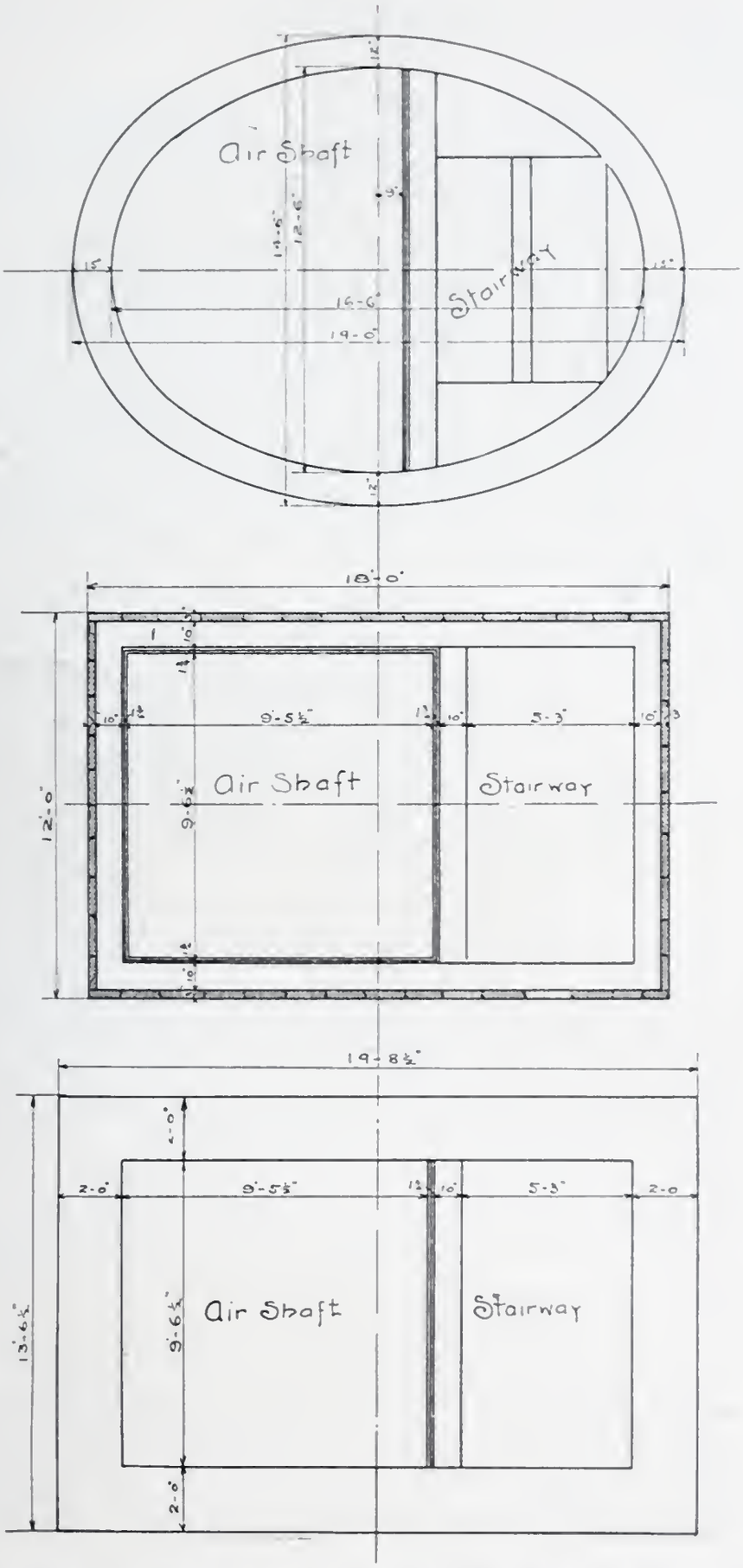
that can be adapted to other localities by substituting the local conditions governing the cost.





Comparative Diagram of Concrete and Timber Lined Main or Hoist Shafts.

The Dravo Contracting Company sunk two shafts for the United States Coal & Coke Co., a subsidiary company of the United States Steel corporation, at Tug river, West Virginia. These shafts were sunk through one vein of coal at 100 feet in depth, and continued through the second vein at 175 feet depth. The air shaft was 14 feet 2 inches on the short axis by 20 feet on the long axis. This shaft was lined for a depth of 45



Comparative Diagram of Concrete and Timber Lined Air Shafts.

feet, in order to shut off the surface water. The concrete was 12 inches thick.

The main hoisting shaft was 17 feet 4 inches on the short axis by 33 feet on the long axis, the concrete being 12 inches thick at the sides and 18 inches thick at the ends. It was a four compartment shaft, including a downcast air way, two hoisting ways and a pipe way. It was concreted throughout on account of the downcast air way and the desire to shut off all the water in the rock, which was successfully done. The cross buntons were held by cast iron boxes built into the concrete, but these boxes were probably unnecessary. In the hoist shaft an average progress of 16 feet per week was made, 20 feet being the maximum. The total excavation in this case amounted to 21 yards per foot of depth.

A paddle concrete mixer was placed at the head of the shaft and the concrete was lowered directly from the discharge spout of the mixer without further handling. While one bucket was lowering, the other was filling; thus no time was lost in delivering concrete to the placing gang. All form work was done at night, and the concreting on the day turn. The forms were built in five foot vertical sections and were used repeatedly.

The cost of labor, mixing, placing forms, lumber, carpenters, hoisting engineers, oil, waste, supplies, sundries and superintendence will amount to about $4.00 to $5.00 per yard, depending upon the size of the shaft and the thickness of the concrete. To this must be added the cost of materials.

A further detailed account of the operations on this job is more elaborately set forth in the "Engineering News" of November 4th, 1904, the author being Mr. Francis Donaldson, who was superintendent of the work.

The following table illustrates the relative cost of elliptical concrete lined shafts, and also the usual rectangular shaft lined with concrete and with timber. It illustrates the great economy of the more permanent concrete shaft. This table refers to the concrete lined shafts illustrated below, and represents closely the practice in this community.

MAIN SHAFT

	Elliptical	Rectangular	
		Timber lined	Concrete lined
Concrete per foot of depth	4½ cu. yds.		5.9 cu. yds.
Excavation " " "	13.5 "	12 cu. yds.	15 "
Timber " " "	90. ft. B. M.	500 ft. B. M.	80 ft. B. M.

COST PER FOOT OF DEPTH

Concrete,	$ 9.00 per cu. yd.	$ 40.50		$ 53.10
Excavation,	5.50 " " "	74.25	$ 66.00	82.50
Timber,	60.00 " M.	5.40	30.00	4 80
Total Cost Main Shaft		$120.15	$ 96.00	$140.40

AIR SHAFT

	Elliptical	Rectangular	
		Timber lined	Concrete lined
Concrete per foot of depth	3 cu. yds.		4 3 cu. yds.
Excavation " " "	8 "	8 cu. yds.	9.9 "
Timber " " "	70 ft. B. M.	450 ft. B. M.	70 ft. B. M.

COST PER FOOT OF DEPTH

Concrete	$10.00 per cu. yd.	$30.00		$ 43.00
Excavation	6.00 " "	48.00	$48.00	59.40
Timber	60.00 " M.	4 20	27.00	4.20
Total Cost Air Shaft		$82.20	$75.00	$106.60

An example of an air and main shaft, each 200 feet in depth, corresponding to the drawings reproduced, would represent an outlay of $34,200.00 for a timber lined rectangular shaft, while the equivalent elliptical concrete lined shaft would cost $40,440.00, both figures including all materials. The difference due to the increased cost of $6,240.00 is more than offset by the fact that it would cost over $15,000.00 to re-timber both shafts, not to mention the loss of time and repairs.

DISCUSSION.

Mr. F. Z. Schellenberg, Mem. Eng. So. W. Pa.—The only elliptical hoisting shaft that has been long known to us is at Grindstone Station. It is lined with brick in cement and was built nearly 20 years ago under W. R. Wilson (once a member of this Society). Following his English experience he departed from standards here, and this shaft was made large—

16 feet clear across, to allow placing his two small cars tandem on a cage.

My experience with an elliptic shaft was in the advantageous driving of an air hole as an upraise from the mine to the surface, 130 feet high, near Long Run church. A core of the broken rock was kept in across the middle by crib facing at ends; it enabled the men to comfortably stand and drill the blast holes overhead and be in good air, as will appear. Making the shaft 12 feet long gave room for clear spaces at both ends; one with plank against crib sticks was smooth to help the fall of the extra excavation material to bottom to be there loaded into cars and hauled out on tracks of mine, the other end was kept open as a manway from bottom to top, and by these end spaces ventilating current circulated over core top. The air-hole arrived neatly in an orchard and operations at the surface were confined to the building of a large ornate chimney; the air-hole becoming a ventilating furnace and stack of larger dimensions than any other known to us.

Some 30 years ago when the larger pumping coal operations began in Westmoreland County with about 200 feet deep shafts, the timbering was all 8x10 horizontal frames, buntons, and spacing posts (about 4 feet long) except toward the very bottom, where 8x12 was used. I preferred oak and had the 3 inch plank, for upright lining around the timbers, sawn off the outside of the logs to get heart sticks.

With the advent of cheap reliable hydraulic cement the thought of its use for concrete lining around in shafts I believe occurred to many of us.

We had an early experience in stopping the falling out of fire-clay, etc., in a tunnel of the mine by use of concrete of lime and ashes on the sides. It was a successful remedy for the evil of caving, due to slaking, of the rock as it was exposed to the air.

Mr. E. K. Morse, Mem. Eng. So. W. Pa.—I have not strength enough in my thumb and finger to break an egg end on, but I can break it easily taken flatwise. I notice that this elliptical shaft has the concrete thin at the sides and thicker at the ends. Is that right?

Mr. Samuel Diescher, Mem. Eng. So. W. Pa.—You can crush an egg taking it flatwise, because the two ends yield. But if the two ends of the oval are butted against firm ground so that they can't yield, they act like abutments on an arch bridge and the weakest point is at the two poles.

Mr. A. C. Beeson, Mem. Eng. So. W. Pa.—I do not see the use in making the shaft elliptical. I know of one concrete shaft designed for the Redstone mine of the Frick Coke Co., which had the curve flattened a great deal, in fact a multiform curve so there was scarcely any waste at the sides of the shaft. It was intended to put down bore holes at each end to take the water pressure off the back of the concrete.

Mr. A. Stucki, Mem. Eng. So. W. Pa.—I think the only way to look at it is to consider it an arch. The flat side should be the thicker of the two.

Mr. F. R. Dravo—There are no considerations by which we can apply the theory of the arch to this lining. As Mr. Diescher pointed out, it cannot yield by moving outward, and the only way it can fail is by coming inward, consequently that removes all possibility of applying the ordinary arch theory.

Suppose we consider that there is a water pressure against the concrete. There cannot be any great amount of water pressure against the concrete because it will leak. I dare say it would leak under a head of fifty feet. But that pressure cannot become active, or hydraulic pressure, if you please, from confinement in the rock, because water does not exist under great pressure in rock, ordinarily speaking. Of course an artesian well is a very different thing. But so far as my observation locally is concerned, it is simply water of seepage, and if that is held it does not establish any great amount of pressure against the linings; and at Tug river they were made perfectly tight with provisions for tapping off the water through the concrete; but afterwards these openings were plugged and no water appeared on the surface of the concrete.

The reason for making the concrete thicker at the ends of the ellipse than on the sides is because it would take the greatest pressure there, if there was any. It is simply a crushing force

that is exerted, and for that reason there should be more concrete to oppose the pressure on the ends.

So far as the elliptical form is concerned, there is no good reason for making it so rather than made up of arcs of circles like the five-centered arch. But you have to avoid getting it too flat on the sides because a section of the concrete might be forced in by conditions which we might not be able to govern. I do not think it a matter of very great probability, but as a matter of judgment I would not make it practically flat. Neither would I make it an ellipse were it not for the fact than an ellipse is just as easy to build as anything else, and just a little easier to lay out on the drawing board than to make something of arcs of a circle that looks almost like an ellipse.

In regard to the water-tightness of the concrete, that is one of its chief advantages, because you can hold the water and you can do it very readily, and you can't do it with brick or stone. That shaft that Mr. Schellenberg mentions at Grindstone is a splendid piece of work, but it leaks like a sieve. The leakage is of no particular disadvantage in that case, and when that shaft was built it was very much cheaper to use brick than concrete. Cement then was worth about $3.00 a barrel and there was not a great deal of experience using it, but with the present price of cement and the fact that so many people know how to use it advantageously, it seems to me it is the best material available.

Mr. E. K. Morse—Did you have any trouble in blasting around green concrete?

Mr. F. R. Dravo—The shooting in the rock we have in this country is not heavy shooting. We do not have such rock around here as they have in Michigan. We have not found that the shooting disturbs the concrete. But the concrete is never within fifty feet of the bottom of the shaft. If we sink a shaft in as good material as we have in West Virginia, we complete the excavation and concrete it from the bottom up. The mass of earth above your shooting is so tremendous that it is hardly probable that the concrete would be injured and in any event it would have the time to set that it would take to sink forty or fifty feet, which would be, say, two weeks.

Mr. A. C. Beeson—If Mr. Dravo did strike a wet shaft, how would he catch the water inside the concrete? I do not agree with the view that he could keep a spring out. I know in No. 1 Continental we got water enough from the rings to run the plant two years. I know he could not have kept that out. In case of a wet shaft, and if the concrete should leak, this water would have to be taken care of and I would like to know how it would be done.

Mr. F. R. Dravo—I was very careful to say in my paper an ordinary amount of water. I meant by that the water that occurs as an infiltration or seepage through the strata, depending more or less on the character of the rock. For an excessive amount of water, the simplest way would be to take paper or canvas, lay it against the rock and concrete between the canvas and your forms forcing the canvas against the rock. You will find that between the canvas and the rock there will be veins formed just like the veins on the back of your hand, all leading to the outlet point, which will be a piece of one or two inch pipe let through the concrete. Between these veins the cement that will leak through the canvas, if canvas is used, will make as good a bond to the rock as it would ordinarily. I do not pretend to say it makes much of a bond to the rock in any case. But owing to the roughness of the rock it takes a grip good enough to carry the lining without any support at the bottom.

At Tug River and at the Washington Coal & Coke Co.'s shafts we built pipes through the concrete where an excessive amount of water occurred and put canvas, or paper, against the rock, controlling the water that way. After the concrete was set for a matter of thirty, forty-five, or sixty days, as the case might be, but set long enough in our judgment to be strong, the pipe was capped and the water controlled. In the case of a considerable quantity of water occurring in a water bearing stratum, and under a head as well, there would be only one thing to do and that would be to put in a water ring and take the water away.

Mr. Samuel Diescher—I know from concrete work that I have had charge of that if there is a spring no matter how

little, it is impossible to stop that spring with concrete. It always dissolves enough of the cement to carry it away. I put thirty inches of concrete on top of a spring that you could not see run, and it was not stopped. If occasionally a bar of iron would be sunk in the concrete and left until the concrete begins to set and then pulled out, the water would find its way through these vents.

Mr. F. R. Dravo—It depends on the head of the spring. If you are able to get on top of the spring a head of concrete that is greater than the head of the water, there will be no difficulty.

PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

VOL. XXI OCTOBER, 1905 No. 7

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The two hundred and fifty-seventh regular meeting of the Engineers' Society of Western Pennsylvania was held at 410 Penn avenue, Pittsburgh, Pa., Tuesday, September 19, 1905, at 8:15 p. m., with 43 members and visitors present. The following gentlemen registered:

MEMBERS.

H. H. Anderson,
George T. Barnsley,
J. M. Camp,
G. M. Campbell,
J. W. Cruikshank,
Robert A. Cummings,
Samuel Diescher,
Edward J. Dittmar,
Franz Engstrom,
N. H. Finley,
M. W. Hogle,
Alex. L. Hoerr,
F. R. Jennings,
W. M. Judd,
John L. Klindworth,
A. C. Knickerbocker,
Robert Linton,
C. Ludlow Livingston,
F. V. McMullin,
L. C. Moore,
A. E. Myers,
Francis S. Rice,
A. Stucki,
Joseph A. Shinn,
Emil Swensson,
Willis Whited,
T. J. Wilkerson,
W. G. Wilkins,
Henry M. Wilson,
C. R. Branson.
Morris Knowles,

VISITORS.

E. Brock,
W. E. Reed,
Frederick A. Russell.

The minutes of the last meeting being in print, by general consent, the reading thereof was dispensed with.

The report of the Board of Direction was read by the Secretary, recommending for membership eight applicants.

On motion, the Secretary was instructed to cast the ballot for their election.

The Board recommended: "That the Society appoint a committee to confer with the city authorities regarding a revision of the building laws of Pittsburgh."

President Diescher: This matter has been before the Board, and is now brought before you so that you may take action thereon if you see proper to do so.

There ought to be adequate building laws and competent supervision, especially so on account of the modern systems of building constructions as combinations of steel, brick and stone, and reinforced concrete systems.

Mr. Robert A. Cummings: It is obvious to all of us that the building laws of Pittsburgh need revision. I do not wish to place myself in the position of arguing for a revision at this time, but I think that as engineers we are collectively responsible for the structural design of buildings, foundations, etc. It, therefore, becomes this Society to take some action in the matter.

President Diescher: All that we can do at this time is to appoint a committee to take this matter up and later on make recommendations as to further action by the Society.

Mr. Emil Swensson: From the president's suggestion that we perhaps cannot come to the conclusion tonight I wish to dissent as I think that we can come to one conclusion at least, and that is whether or not we should meddle with it. When that point is decided, we can consider the question of appointing a committee. I for one am distinctly and consistently opposed to meddling with the subject in the manner suggested by the Board. As a Society we ought to profit by past experience, and especially by failures to make ourselves heard in matters which come under the province of politics. We have upon several occasions in the past proffered our good offices and assistance in such matters, but without getting

much consideration or accomplishing anything. We probably do not go about it in the right way and accomplish nothing, just the same as other important bodies of men in this city and others. Our legislative bodies, whether city or state, do not seem to appreciate such efforts and they take up important matters like this at their own time and convenience.

I will quote a couple of our experiences as a Society:

One was our effort in the matter of good roads with our State Legislature. With our honest efforts and time and our own money we endeavored to impress upon our legislative body the necessity of enacting certain laws, but without accomplishing anything. We also as a Society joined our efforts with other scientific and business bodies in this city to look into the question of a pure water supply and filtration. The committee appointed was a good one, the work done was very creditable, it being put in book form and presented to the public, as well as our municipal authorities. Very little attention was given to our efforts, but at their own convenience the municipal authorities appointed a committee of prominent citizens on the matter of water supply and filtration. This committee, not being experienced in such matters, employed their own engineers to go over the same ground that our Society had done. None of those that had labored long and faithfully on the report were employed or consulted or have had any part whatever in the matter since.

In the late agitation for the removal of the hump we know what success the Chamber of Commerce had. However, if we deem it so important that it is imperative for us, as Engineers, to take up this matter, we should not go about it as a Society, but quietly adopt political methods and have some of our legislative friends introduce bills or resolutions at the right time and in the right place to have it passed by the bodies. I believe, therefore, that our Board of Direction should further look into the matter and get necessary data, and if need be, themselves take up the matter on this line.

Mr. Morris Knowles: I am not sure at all but what the Engineers' Society should make itself felt in this matter, but as to the particular method of procedure, this should have

careful consideration. First the way should be felt to know whether such suggestions would be kindly received; also whether things are in a ripe condition for this topic to be agitated. There are times when matters of this sort can be taken up with profit; there are times when it is absolutely impossible to have a matter of any kind of engineering considered.

It seems to me that it would be wise if there were a preliminary step through a committee of the Board of Direction, or better still by the Secretary, on account of calling less attention to the matter before we are prepared to go ahead, to learn what has been done in other places. I have in mind that something was done in Boston at one time by the co-operation of the engineers and the architects, but that they were invited to do it, however. I think it would be worth while finding out from the secretary of the Boston society just what was done, probably also, in Philadelphia, Buffalo and Chicago. Let us carefully consider and profit by their experience and then decide whether we want to take this step. We may find that such a thing would be welcomed.

Mr. Emil Swensson: I move that this matter be referred back to the Board for further consideration and study, and report to the Society not later than the November meeting.

Frederick A. Russell, President of the Pittsburgh Chapter of the American Institute of Architects, was invited to address the Society.

Mr. Frederick A. Russell: The Pittsburgh Chapter of the American Institute of Architects took up this matter last winter, considering it was one of the most important matters demanding consideration, and that it was possibly their province to take the initiative. A committee was appointed to make investigation as to what had been done in other places, and to report with recommendation to the Chapter.

This committee went into the matter quite thoroughly, and corresponded with the chapters in various other cities, and found that in Boston they have revised the building laws very fully, and perhaps better than in any other city in the country. In Cleveland they have produced a new code that is said to be a model. In Chicago and numerous other cities,

if they have not already formulated new codes, they at least have the matter under consideration. In other words, there seems to be a general movement in all of the greater cities of the country to consider the revision of the building laws.

I think we all realize that the law here in Pittsburgh needs revision quite as much as that in any other city in the country. The architects appreciate this, if the engineers do not. The building law, however, as many of you know, is created by Act of Assembly, and not by the city authorities, and in order therefore for anything to be accomplished in this matter, it is necessary that it shall be done through the Legislature.

The committee of the architects above referred to made their report to the Chapter, based principally upon the proceeding that was followed in Boston, where the Legislature was petitioned to cause a law to be passed creating a commission to investigate the expediency of revising the building law, and to report, and accompany their report with drafts of such bills as may be necessary to carry its recommendation into effect.

That commission was composed of architects, engineers, builders and underwriters, I believe, all men of the highest standing and who served without pay. They spent several months formulating their suggestions and these were finally passed by the Legislature and constitute the new Boston code which is now considered to be one of the best in the country.

In the meantime we had corresponded with some of the principal architects in Philadelphia relative to their views concerning the necessity or desirability of any revision of their building code, which is the law governing cities of the first class. They advised us that while there were points that might possibly be improved in their code, yet they considered it reasonably satisfactory in its present shape, and did not feel it imperative to take the matter up. It, therefore, occurred to us that possibly the simplest method to pursue would be to petition to have the law as applied to cities of the first class made applicable as well to cities of the second class, which would be the simpler method and the one most likely to be accomplished, rather than to start from the beginning

and endeavor to formulate an entirely new code and then have it adopted. The work attending the latter would be a colossal task if sufficiently thoroughly done to be of proper use and the task is almost equally as difficult to find the individuals capable to accomplish this who have the necessary time to devote to it.

The report of the architect's committee included also a resolution to the effect that the Engineers' Society should be asked to co-operate with the architects in this matter as well as the Bar Association, the Builders Exchange and Underwriters of Allegheny county.

Mr. Morris Knowles: Have the other associations taken any action?

Mr. Frederick A. Russell: They have not, because we have not yet presented the matter to them. We discovered that the legislature adjourned last spring for two years and does not meet again until a year from this fall, and it would be impossible for anything definite to be done until then. But, of course, in the meantime there is work to be done.

Mr. W. G. Wilkins: It seems to me it would be better for our Society and the architects, too, to defer action until just before the Legislature meets. If we refer the matter to the members of the Legislature now they will have forgotten all about it inside of the year.

Mr. Morris Knowles: I think it would be an act of courtesy if Mr. Swensson will allow it as an amendment to his motion, that in the consideration of this matter the Board of Direction be requested to co-operate with the proper representatives of the other societies in this place, and also with those of the societies of the other cities of the state.

Amendment was accepted and being put to vote was carried.

President Diescher: Has Mr. Barnsley, chairman of the Committee on New Quarters any report?

Mr. George T. Barnsley: Following the appointment of the committee to meet representative committees of the Railway Club, the Traffic Club and the Foundrymen's Association a general meeting of these committees was held in the latter

part of March of this year, and they organized by electing myself as chairman of the general committee, and a representative of the Railway Club as secretary. We met and thoroughly discussed this matter. There was a whole lot said. There were fifteen of them to talk, and the session was long. There were some points developed which were to me somewhat disappointing, as there was so much talk regarding ways and means and what we should do and what we should get, but I didn't hear anybody saying anything which would carry with it responsibility. They seemed to have one idea in particular, that we should have quarters in some hotel where we could get something to eat, and a place to smoke. They did not take seriously to the idea, which to the Engineers' Society is of the utmost importance, the maintainance of quarters which any permanent organization like this must have for its success. I didn't call another formal meeting of that committee until last Friday night. The result of that call was about the same sort of talk as before. So I brought the matter to a focus in this way. I made known to the general committee that from the standpoint of this organization we would have suitable quarters regardless of what the other organizations wanted, and those quarters must consist of an auditorium, library, reading room, reception room, secretary's office, toilet and coat rooms and kitchen. I said very plainly that as the Engineers' Society of Western Pennsylvania was the oldest and largest and most important of these organizations and the only one which was incorporated and legally responsible, and the fact that we needed more than the others said they needed, we should be the parent organization in anything that might be done; we should take the initiative, and let the others consider as to whether they would join and be tenants in common in any quarters we might select in the future.

A motion was made something like this: "That the Engineers' Society of Western Pennsylvania should take the initiative in the matter of society quarters, and afterwards confer with the Pittsburgh Railway Club, the Traffic Club and the Foundrymen's Association as to participating as tenants." That to my mind is the right thing to do in this matter. I do

not think it is worth while to meet members of the other organiations with such results as we got. I would recommend that this society act on these lines and independently take up the matter and go ahead with it without any idea of the other organizations at all, and decide what we are going to do after the lease to this property expires, April 1st, 1906. Then, if agreeable and the quarters are such that others could occupy them, we could invite the others to participate and make some arrangement by which they would either pay a rental or a proportionate amount of the expenses. Any quarters which we might select would be more than enough for any of the other organizations, and the only thing that could be gained by having the others join would be that we might arrange for something a little more elaborate than we would feel able to provide for ourselves, single-handed.

On motion Mr. Barnsley's committee was instructed to see what they can do in the way of getting quarters, and report to the society.

Mr. W. Edgar Reed then read a paper on Electric Motors and Their Applications.

After discussion the meeting adjourned at 9:45 p. m.

F. V. McMULLIN, Secretary.

NEW MEMBERS.

NAME.	OCCUPATIONS AND ADDRESS.	ENDORSED BY
CHAS. B. JUDD,	Civil Engineer, 1211 Park Building, Pittsburgh, Pa. h. 2006 Delaware ave., Swissvale, Pa.	W. C. Hawley, W. G. Wilkins, A. Stucki
HERRMAN W. KLEIN,	Engineer, Mackintosh, Hemphill & Co. h. 600 Hill ave., Wilkinsburg, Pa.	Joseph Fawell, F. C. Schellenberg, Samuel Diescher.
J. W. HENDERSON,	Superintendent, Central Car Wheel Co., McKees Rocks, Pa. h. 45 Grant ave., Bellevue, Pa.	H. H. Anderson, Harvey Allen, F. R. Jennings.
SAML. F. LONG,	Mechanical Engineer, Wheeling Mold and Foundry Co., Wheeling, W. Va.	Samuel Diescher, F. Z. Schellenberg, G. E. Flanagan.
P. A. MEYER,	Engineer, McKeesport & Greensburg Railway Co., Barclay Building, Greensburg, Pa.	Ernest P. Whitten, Newton L. Hopkins, Saml. A. Taylor.
ANTHONY VICTORIN,	Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa,	Chas. F. Scott, S. M. Kintner, P. M. Lincoln.
JOSY VOLLKOMMER,	Engineer, 1112 Empire Building, Pittsburgh, Pa.	J. Richard Kommer, F. V. McMullin, Samuel Diescher

MONTHLY MEETING OF BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at 410 Penn avenue, Pittsburgh, Pa., Saturday evening, September 16, 1905, at 8:25 p. m.

Present: Diescher, Flanagan, Lyons, Barnsley and Secretary.

The death of James McQuiston was reported.

The following resignations were accepted: H. J. Leacock, H. A. Brassert.

On motion it was ordered that the safe deposit box should only be opened in the presence of both the Secretary and Treasurer.

On motion the Finance Committee was ordered to make arrangements for bonding the Treasurer and Secretary, beginning with the year 1906, society to pay for same.

Report of the Publication Committee recommending that Mr. S. W. Armor be engaged as advertising solicitor at a salary of $75.00 per month and a 12½ per cent commission on all business accepted by the board, was on motion, accepted.

On motion adjourned at 10:45 p. m.

F. V. McMULLIN, Secretary.

SPECIAL MEETING OF THE BOARD OF DIRECTION

A special meeting of the Board of Direction was held at 410 Penn avenue, Pittsburgh, Pa., July 27, 1905, at 9:00 p. m.

Present: Messrs. Kintner, Lyons, Whited and Knowles, also Mr. Winter as counsel and the Secretary.

In the absence of the President, Vice President Kintner presided.

Bills were paid amounting to $377.73.

Mr. Knowles reported for the Advertising Committee that an agreement had been reached with Mr. F. A. Ensign, by which the society was to pay Mr. Ensign 50 per cent. commission on all unexpired contracts for advertising solicited by him for the Proceedings; he to deliver contracts to the society on expiration of same, in consideration of which Mr. Ensign released all claim for the right to place advertisements in the proceedings.

On motion the name of the Advertising Committee was changed to Publication Committee.

On motion the name of the Auditing Committee was changed to Finance Committee.

On motion the meeting adjourned at 10:30 p. m.

F. V. McMULLIN, Secretary.

CHEMICAL SECTION.

The regular monthly meeting of the section was held with the Pittsburgh Section of the American Chemical Society, Thursday, September 21, 1905.

The meeting was called to order at 8:30 p. m. The Chairman and Vice Chairman being absent, Mr. H. E. Walters was elected Chairman Pro Tem. Thirty-two members and visitors were present.

Mr. John R. Mardick, of DuBois, Pa., presented to the meeting "A co-operative plan for systematic research work." The plan calls for closer relations between engineers and research workers, and is intended to lead to research work along immediately practical lines. After discussion the meeting adjourned at 9:30 p. m.

HARRISON W. CRAVER, Secretary, C. S.

STRUCTURAL SECTION.

The regular monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held in the Society House, 410 Penn avenue, Tuesday evening, September 26, 1905.

The meeting was called to order at 8:10 p. m. by Chairman E. K. Morse, 32 members and visitors present.

There being no committee reports, unfinished, or new business brought before the meeting the Chairman then introduced the speaker of the evening, Mr. Paul Kreutzpointner, non-member, who read a paper on "The American Society for Testing Materials; Its National Economic Importance and Aims."

After answering some questions from several of the members the meeting adjourned at 10:25 p. m.

T. J. WILKERSON, Secretary, S. S.

*ELECTRIC MOTORS AND THEIR APPLICATIONS.

W. EDGAR REED,
Non-Member.

Electric motors are either of the alternating or continuous current type, depending upon the kind of current upon which they are designed to operate. For convenience in applying motors, they may be classified according to their operating characteristics. The characteristics which are of the most importance in this classification are:

(1) The speed-torque and speed-horse-power characteristics, or the automatic variation of speed for different torques and horse-power outputs required of the motor.

(2) The maximum starting and running torque and horse-power of the motor.

(3) The rating of the motor, or the time it will carry its normal load with a given rise in temperature.

(4) The efficiency and, for alternating current motors, the power-factor.

In the following paragraphs the motors are classified according to their speed-torque characteristics and a statement is then made regarding their other important operating characteristics which are useful in making applications.

CLASSIFICATION ACCORDING TO CHARACTERISTICS.

Constant Speed.

Variable Speed.

Compound Type of Motor.

The Constant Speed Motor gives under normal conditions practically constant speed for all torques and horse-power outputs within the range of the motor. The synchronous motor gives absolutely constant speed if the cycles of the circuit upon which it operates remain constant. The other types do not give constant speed but the variation is small within the capacity range of the motor. This variation differs

* Meeting of the Society, September 19, 1905.

for different sizes of motors and is generally a little less as the size increases. It can also be changed in the design of the machine. Five per cent. may be taken as a very general figure to get some idea of the average value of this variation from no load to full load speed. The general characteristics of constant speed motors under varying loads is shown in Fig. 1. These

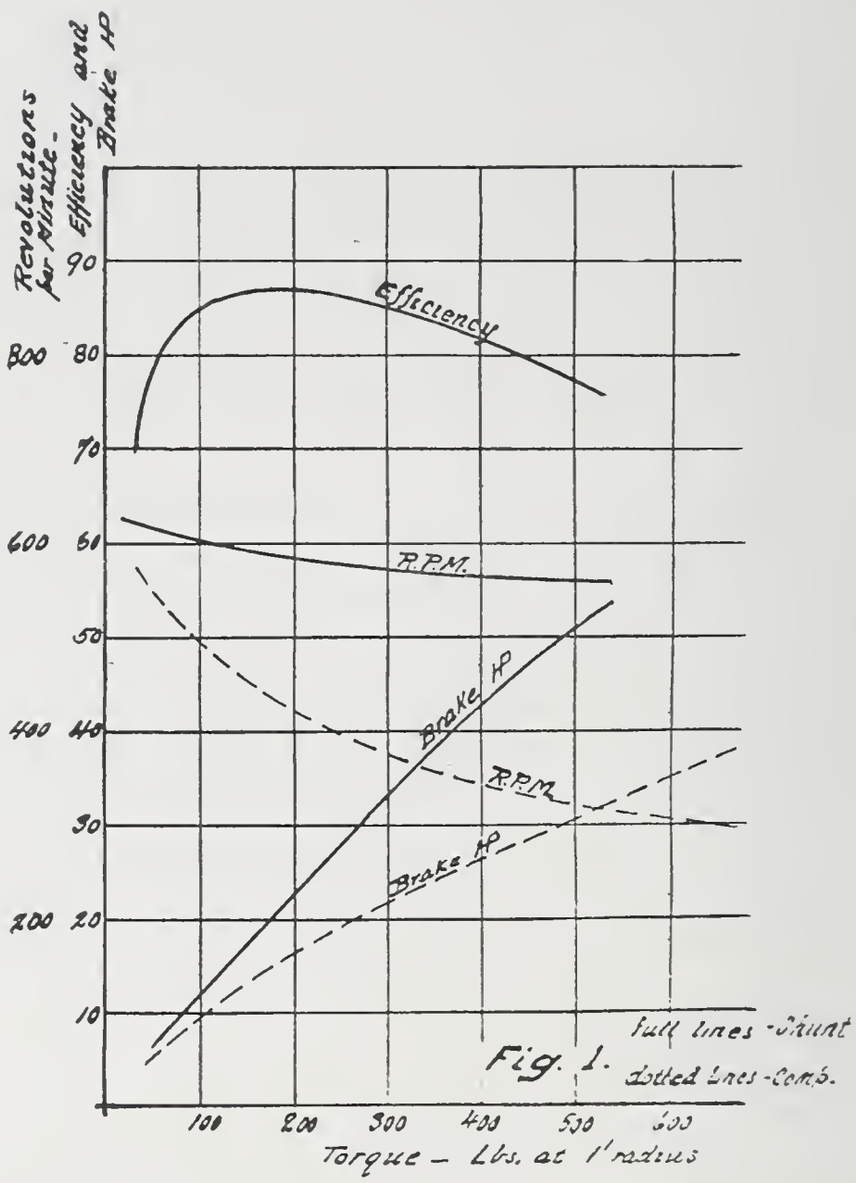


Fig. 1.

are curves of a shunt wound D. C. motor, but they represent the general characteristics of other constant speed motors. In these curves the torque developed by the motor is taken as abscissae and r. p. m. brake horse-power, and efficiency in per cent. as ordinates. These curves show that the speed remains practically constant for all torques and horse-powers developed up to about 50 per cent. overload. The motor automatically

adjusts itself to give constant speed when different loads are required of it. The efficiency is zero at no load but rises rapidly as the load comes on, reaching a maximum somewhere near full load and then gradually dropping off at heavy overloads. The brake horse-power which is proportional to speed and torque is practically a straight line for loads up to about full load, dropping off gradually with heavy overloads. The different types of constant speed motors are given in the following table which is followed by a statement of some of the special characteristics of the machines.

Constant Speed Variable Torque	Continuous Current	Shunt Wound		
	Alternating Current	Induction	Single-phase	
			Poly-phase	Wound Rotor
				Short-Circuited Rotor
		Synchronous	Single-phase	
			Poly-phase	

The continuous current constant speed motors are shunt wound and are generally known by this name. The alternating current motors are of the induction or synchronous types and may be either single or polyphase. The induction motors may be of the short-circuited rotor or of the wound rotor type, with or without collector rings and brushes.

The single-phase induction motor is at the present time generally built only in the smaller sizes and for operation upon lighting circuits. When a sufficient number or when larger motors are required polyphase power circuits are installed for taking care of this kind of service. The single-phase motor generally has a small starting torque and requires fairly large line current to start it even without load. These motors are generally supplied with centrifugal friction clutch pulleys which do not take up the load until the motor has nearly reached full speed. At this speed the motors generally develop from 25 to 50 per cent. more than full load torque, and will then take their normal load and bring it up to full speed.

Although the synchronous motor gives a very constant speed it has no starting torque and is not a self-starting motor, but must be brought up to speed by some outside means and

must be synchronized with the circuit upon which it is to operate before it can be connected to this circuit. A continuous current must also be available for the excitation of its field. Some special arrangements have been tried for making the synchronous motor self-starting, but on account of the low torque developed and large current taken from the line they have not been generally used. These disadvantages prevent the application of this motor in many industries where constant speed is desired and limit its use to certain kinds of work requiring very few starts and a very small or no starting torque. It may be applied advantageously to motor-generator sets, and especially when the generator can be used for starting the set. By properly adjusting the field current of a synchronous motor the supply currents may be made to lead instead of lag behind the line voltage. The motor can in this way be used to control the power factor of the system. Very few single phase synchronous motors are used—most of them being polyphase.

Shunt wound continuous current and polyphase induction motors have very good general characteristics, and do not possess some of the undesirable characteristics which limit the usefulness of the other constant speed motors already described. They have been applied in nearly all the industries where this type of motor can be used and are found much more often than the other types. The polyphase induction motors are generally made with a short-circuited rotor or with a wound rotor arranged in such a way that resistance can be inserted in its circuit at the moment of starting up in order to reduce the starting current drawn from the line. This is especially important when the motor is large compared with the generating station which supplies the power, or when very good voltage regulation of the circuit is desired. They are especially suited for polyphase lighting circuits because the starting current for a given torque can be reduced to almost the same value as the running current when developing the same torque, or the starting current for developing full load torque is only slightly in excess of the full load current of the

motor. The starting resistance may be mounted inside or outside of the brackets and may be entirely enclosed for use in damp places or where explosive dust and gases are found, such as mines, cotton mills, glucose factories, etc.

The starting current of the motor having the short-circuited rotor can be reduced by increasing the resistance of the bars or the short-circuiting ring but the speed regulation becomes poorer as this resistance is increased. This type is adopted when the size of the individual motor is small compared with the capacity of the generating station and when the voltage regulation does not have to be exceedingly good, if large motors are used. This type of motor is the simplest made. It has no sliding contacts and requires the least amount of attention and maintenance.

In order to give a general idea of the values of the starting and maximum torques and the corresponding currents taken from the line for the constant speed motors, the following comparative table is given. These values can be changed in any particular design to obtain specific results, but the table gives the average values for standard motors now built by the best manufacturers:

TABLE No. I.

		TIMES FULL LOAD Amps. in line for full load starting torque	Max. starting torque x full load torque	TIMES FULL LOAD Amps. in line for max. starting torque
Shunt wound—Continuous Current		1.0	2.5	2.5
Polyphase Induction	short-circuited rotor	3.0	2 to 2.5	6 to 7.5
	wound rotor	1.2	2.	2.4
Single phase Induction	with clutch pulley	2½–3½	1¼ to 1½	2½ to 3½
Synchronous		No starting torque	0.	....

Ratings. The temperature rise of both the alternating and continuous current motors is in general about 40-deg. C. for continuous operation at full load. The motors will stand 25 per cent. overload for two hours, with 50-deg.C. rise and 50 per cent. overload for one hour, without injury; also, 75 to 100 per cent. overload momentarily.

In general, then, for constant speed work where a very good starting torque is required and starting is not very frequent, the continuous current shunt and polyphase induction motors are generally used. When the starting torque is zero and some other means is used for bringing up to speed, the synchoronous motor will give very good speed regulation, and when only single phase circuits are available, the single phase induction motor is used.

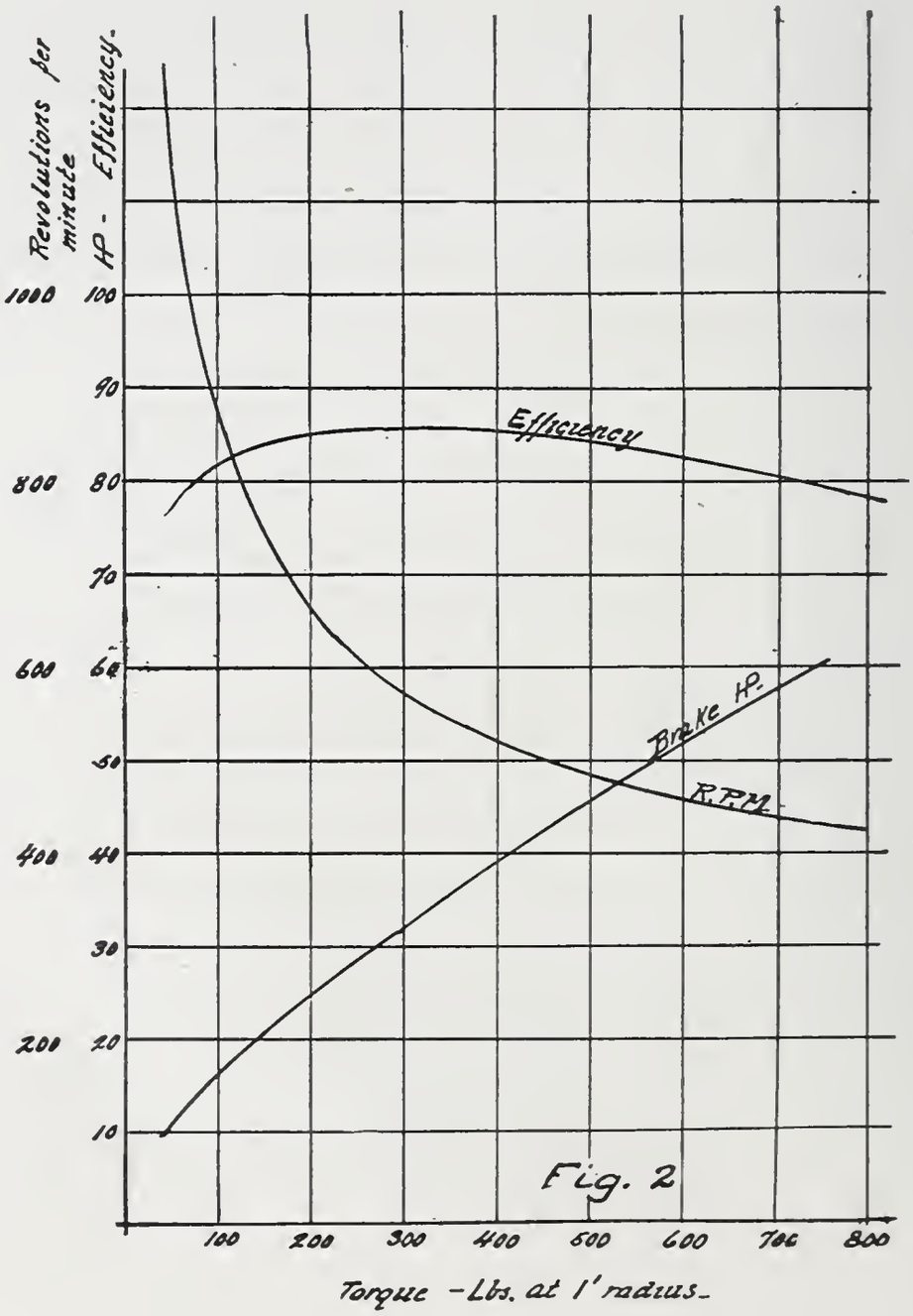


Fig. 2

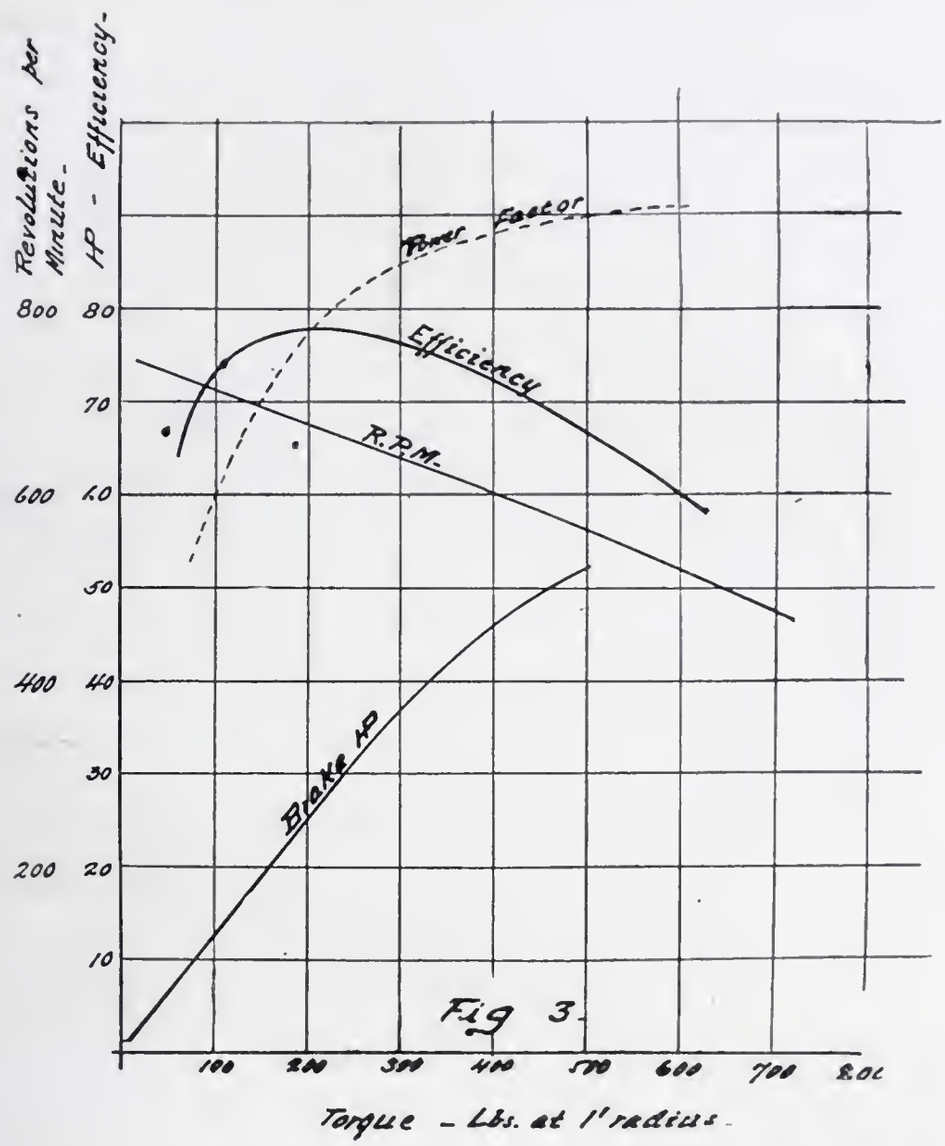


Fig 3.

THE VARIABLE SPEED MOTOR automatically gives great variations in speed for the different torques and horsepower outputs required of it. This variation is different for different designs of motors, but as a very general figure to compare with the other types, we can say that this variation for series wound motors will be from 40 to 75 per cent. increase when the load is reduced to half the normal value and for polyphase induction motors under the same variation of load, the speed will increase from 10 to 15 per cent. This variation for equal percentage change in load will be different for different parts of the speed curve, as it has not a straight line form. The general characteristics of this type of motor are shown in Figs. 2 and 3; Fig. 2 shows the series wound continuous, or single-phase series wound alternating current motor, and Fig. 3

shows the polyphase induction motor. The same quantities are used for abscissae and ordinates as in Fig. 1. The characteristics of the motors as shown in these figures are quite similar to each other except for the speed curves which have a different flexion, the general form of the curves, except the speed curve, being nearly the same as those in Fig. 1. These curves show that the speed of the induction motor approaches a maximum limit when the load is decreased. This limit is definite and is equal to the alternations of the circuit divided by the number of poles of the motor. The speed of the series motor also continues to increase as the load is diminished but at very light loads they are liable to run much too fast. This motor should therefore never be run at very light loads or empty, as it may run off and burst. The different types of variable speed motors are shown in the following table:

- Variable Speed Variable Torque
  - Continuous Current
    - Series Wound
  - Alternating Current
    - Single-phase Series Commutator
    - Poly-phase Induction
      - Wound Rotor
      - Short-Circuited Rotor

There is given below a table showing the maximum starting torques and the current required from the line to develop this torque, together with the current required to give full load starting torque:

TABLE No. 2.

		TIMES FULL LOAD Amps. in line for full load torque	Max. starting torque	TIMES FULL LOAD Current to give this torque
Series	continuous current	1.0	5 to 6	2.5
Series	alternating current single-phase	1.0	5 to 6	2.5
Induction polyphase	short-circuited rotor	1¾-2¼	4 to 5	8–12
	wound rotor	1.2	3–4	3½–5

Comparing this table with table No. 1 we find that the polyphase induction motor is given for both constant and variable speed. A slight difference in the design of the short-circuited rotor motor will change a constant speed motor requiring fairly large current from the line at starting, to a variable speed motor requiring much less current from the line for the same starting torque. The wound rotor motor can also be easily changed from a constant to a variable speed motor by increasing the resistance in the rotor windings. If external resistance is inserted in the windings of constant speed motors at starting to keep down the starting current, it is cut out of the circuit after the motors are started. This is done to get a good speed regulation and high efficiency. In order to obtain the slow speeds desired for variable speed work some of this resistance is left in the circuit. The capacity of the resistance in this case must therefore be much larger than that used for constant speed motors as it must remain in the circuit for a longer time.

Note also the difference in the values of the current from the line for constant and for variable speed motors when developing full load starting torque, and the difference in starting torque that is developed with the same current. This comparison shows why variable speed motors are used for work requiring frequent starts and large torques.

Ratings. Since these motors are run at variable speeds and outputs, there is no definite horse-power rating that will easily represent the temperature rise of the motor under variable speeds and loads, but in order to have some basis of comparison for different size motors, they are generally rated at the horse-power they will develop for one hour with a temperature rise of 40, 60 or 75-deg. C. Or curves are made which show how long the motors will run at different outputs for the same temperature rise. The limit of the maximum rating of a variable speed motor depends upon the losses in the motor and upon the commutation, and the best way to determine whether the motor is large enough for a particular service is not by the horsepower rating but by getting the average

losses during a certain length of time or cycle of operations and determining whether it can stand these average losses without undue temperature rise. The maximum torque required must also be considered to see if the motor can develop this torque without undue sparking and heating.

This type of motor on account of giving great variation in speed for changes of load, is not suited for constant speed work and on account of its good starting characteristics, as shown in the table, and the small amount of current required to give this starting torque, it is especially suited for work requiring frequent starts, such as cranes, elevators, railways, etc.

Compound Type of Motor. The compound wound motor has some of the characteristics of the constant speed and some of those of the variable speed motor. The speed variation with change in load is greater than that for the constant speed motor and less than that for the variable speed motor. The maximum starting torque is greater than that for the constant speed and less than that for the variable speed motor. The current for a given starting torque is more than that for the variable speed motor and less than that for the constant speed motor. Fig. No. 1 dotted shows the general characteristics of this type of motor. The curves are plotted similarly and are similar in general form to the preceding curves with the exception of the speed curve which is a compromise between that of the variable and that of constant speed motor. In different designs the starting and speed characteristics can be changed greatly.

The so-called compound wound motor is only of the continuous current type but polyphase induction motors of the short circuited or wound rotor types are made which have nearly the same operating characteristics. The different types of motors having these characteristics are given in the following table:

Compound Types	Continuous Current	Compound Wound	
	Alternating Current	Induction Polyphase	Short Circuited Rotor
			Wound Rotor

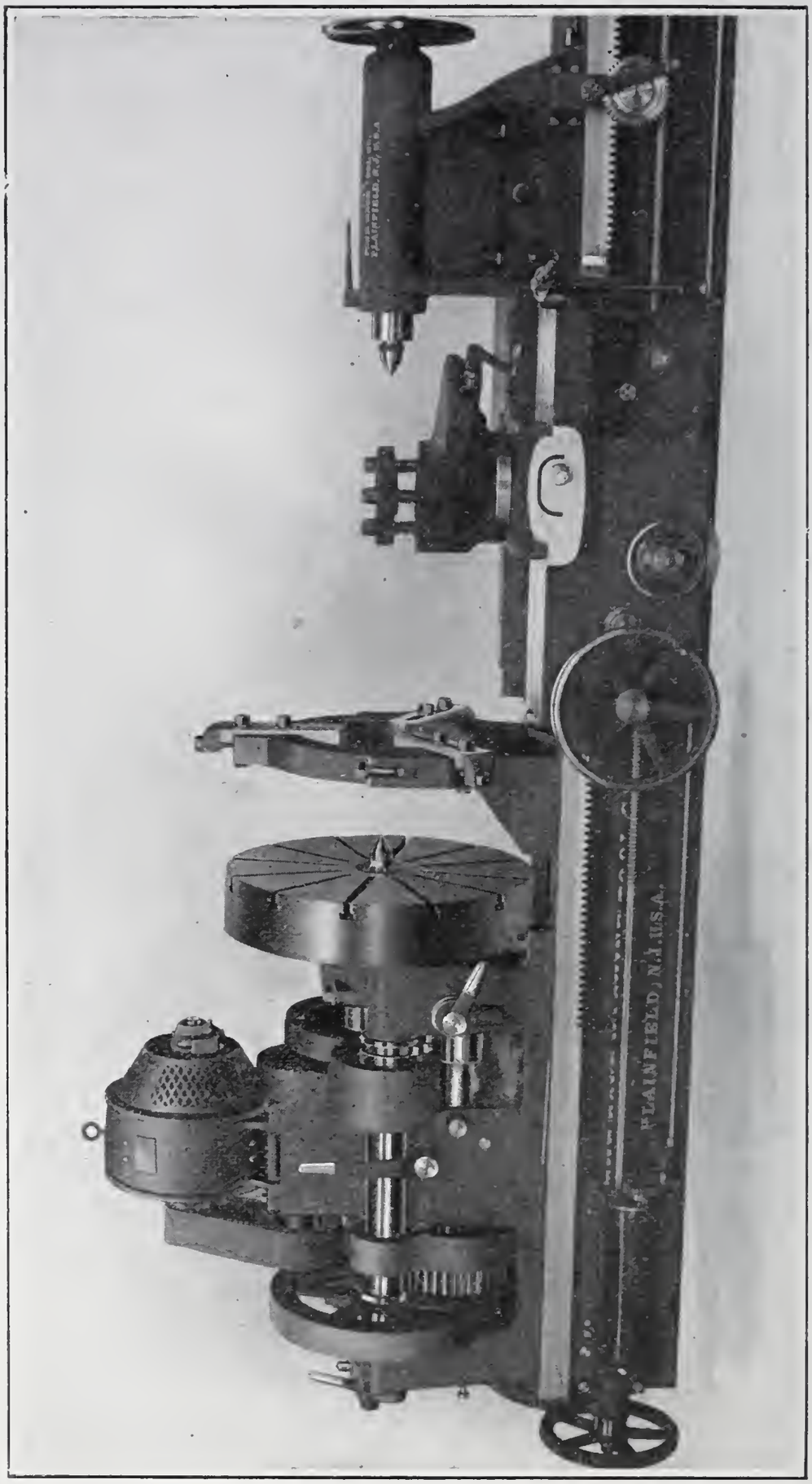
The compound type of motor then has fairly good starting torque, and at the same time gives average speed variation for different loads, the maximum speed being limited even at no load. It is therefore applicable for work requiring fairly heavy starting torque or frequent starts and reversals, and also for operation at fairly constant speed for certain lengths of time. As an example of the application of this type of motor may be given printing presses and machine tools, like planers, shapers, etc., where reciprocating motion is desired, this motor being especially useful in holding down the rush of current from the line at the moment of reversal when the torque required is a maximum.

The value of the current in the line for developing full load starting torque, and the maximum starting torque will be intermediate between the corresponding values for the constant and variable speed motors. These values can be changed within wide limits by making different designs. Good starting torques may be obtained with small starting current and poor speed regulation or good speed regulation may be obtained with a smaller starting torque and proportionately greater starting current for this torque.

These motors are given horsepower ratings for continuous operation and in general give the same percentage overloads and temperature rise for these loads as are given for the constant speed motor, the starting torque being greater than that of constant speed motors.

SPEED CONTROL.

The performance of the different types of motors under uniform conditions of constant voltage, cycles, rotor resistance, etc., has been described. The performances are changed, however, if some of these factors are changed. If the voltage applied to the armature of a shunt motor or the strength of its field magnetism be varied, the speed will be changed accordingly. If the field magnetism remains constant and the armature voltage is reduced, the speed will be reduced in the same proportion, and will then remain constant at this lower speed so long as the above conditions remain unchanged. As



Continuous current shunt motor operating lathe. Variation of field strength for different speed.

the resistance of the rotor of the wound-rotor induction motor is increased the speed diminishes, or as the voltage applied to any induction motor is diminished the speed diminishes. If these factors are changed for the variable speed motors, their speeds will also change accordingly. There are a great many methods of varying the speed of motors which are too numerous to take up in this paper. One of these is the interpolar motor which permits of a great variation in speed on the minimum size frame.

The system of operating apparatus at any one of a different number of speeds is known as variable speed control and it renders motors especially applicable to work which requires small increments of speed over a wide range. This control is especially suitable to the operation of continuous current shunt motors for driving machine tools whereby rapid and economical production is attained. It is also applied to variable speed motors in crane and railway work, etc.

All the motors described above can be arranged for ceiling, wall and floor suspensions as well as horizontal and vertical operation. They can be entirely enclosed if necessary for use in damp places or where there are explosive gases or dust. They can also be arranged so that back gears can be attached to the frame and can be adjusted to suit many special requirements. When the motor is enclosed without air or other method of cooling the rating of a given frame will have to be reduced in order to keep the temperature within safe limits.

EXAMPLES OF APPLICATIONS.

The general characteristics of the different types of motors have been described giving the important advantages of one type over the other. There will now be given a few examples of the applications of these motors as general information. More than one type of motor can frequently be used for the same class of work. Special conditions may influence the choice of the motor and before any decision can be made it is necessary to know thoroughly all the conditions of the service. It is almost impossible to give a complete list of ap-

plications in this paper and the examples given only cover a small part of the field. If other applications are of interest to members, it is hoped they will be taken up in this discussion.

Constant Speed Motors. Line shafting requiring fairly constant speed and infrequent starting.

High and slow speed centrifugal and reciprocating pumps.

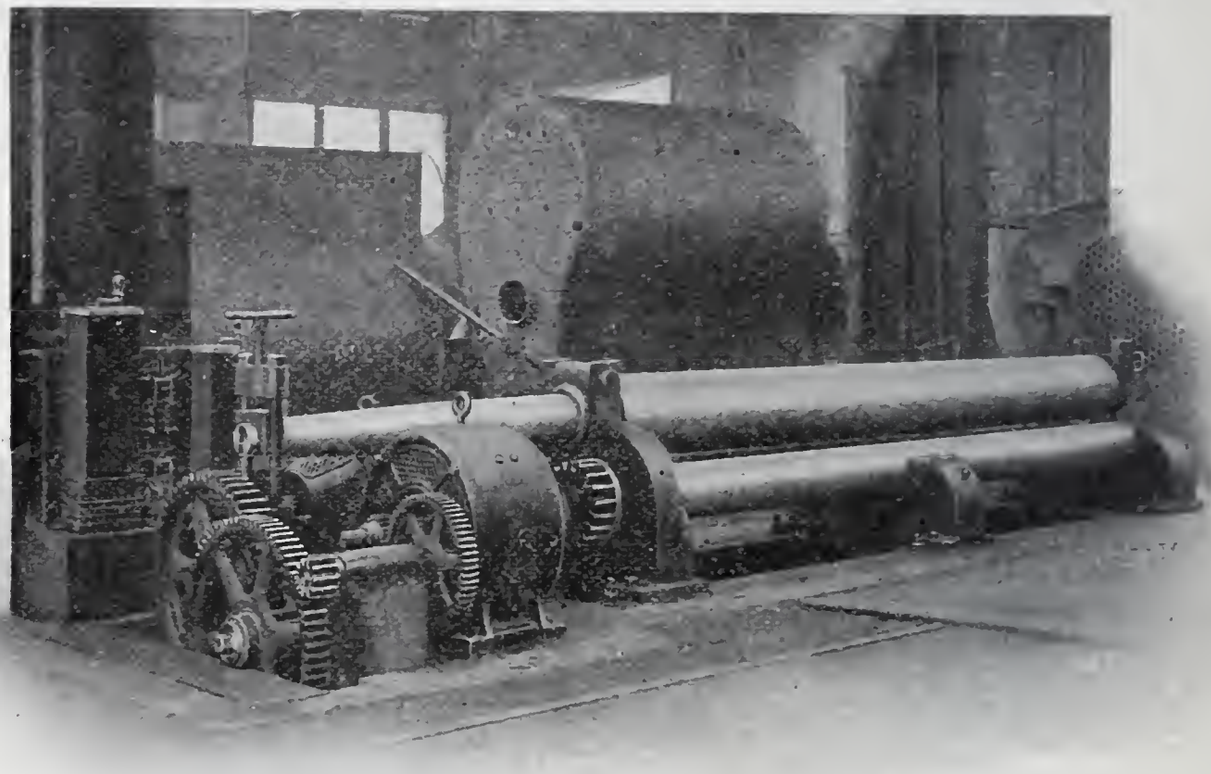
Air compressors, blowers and fans.

Wood working machinery, lathes, boring mills, circular and band saws, etc., and rotary motion machine tools.

Shoe making machinery.

Laundry machinery.

Hydraulic elevators, etc., etc.



Compound motor operating bending rolls.

Variable Speed Motors. Cranes, elevators, hoists, railways, etc.

For railway work requiring frequent stops and high average speed, good starting torque is one of the most important characteristics the motor should have. After acceleration the

motor runs but a very short time at full speed before the power is shut off and brakes are applied—the tables given show that in comparison with the other types the series motor gives the maximum starting torque for a given line current, and this with the automatic reduction in speed and consequently in power as the load comes on are the principal reasons why the series motor is applied universally for railway work.

Whether alternating or continuous current motors will be used in the future for street railway work depends more upon the cost of generation and transmission of power than upon the characteristics of the individual motor.

Crane service can be compared closely to railway work as regards starting and running conditions and practically the same types of motor can be used for this as for railway work.

MOTORS HAVING COMPOUND CHARACTERISTICS:

Hoists, elevators and cranes.

Printing presses.

Reciprocating motion machine tools.

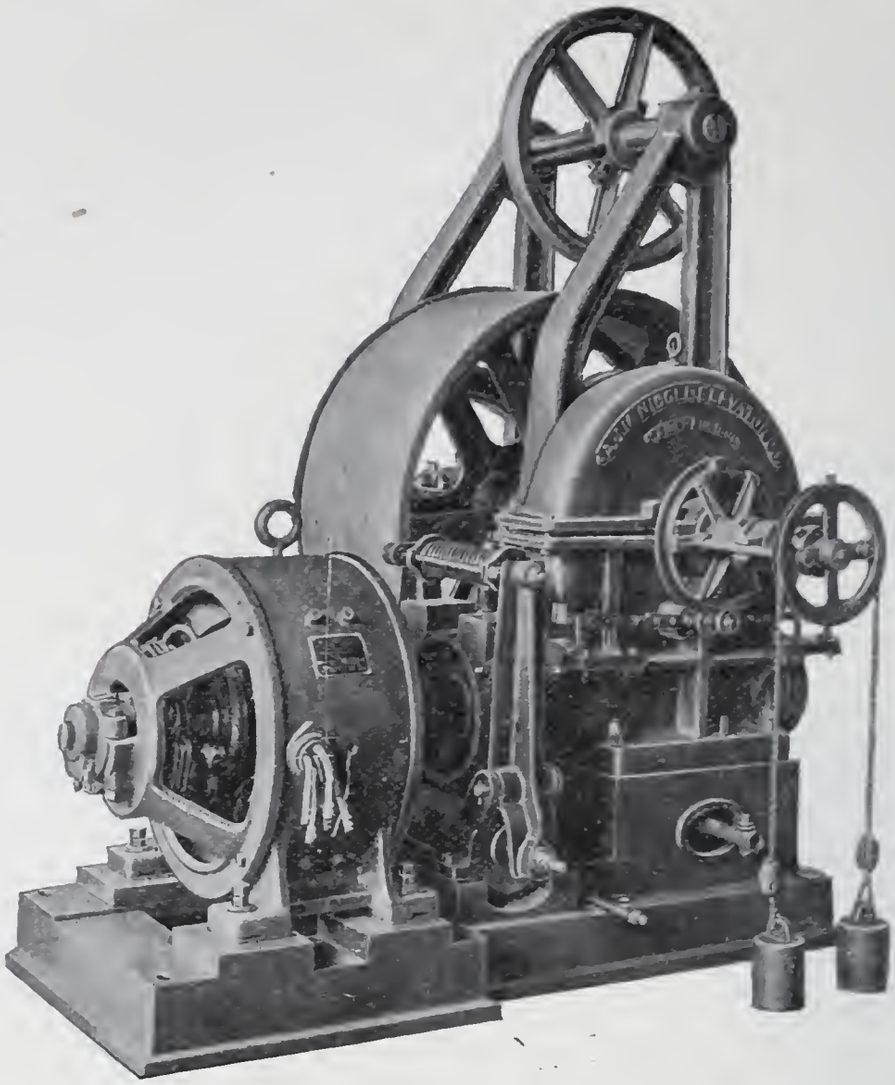
Bending rolls.

Roller-beds, etc., etc.

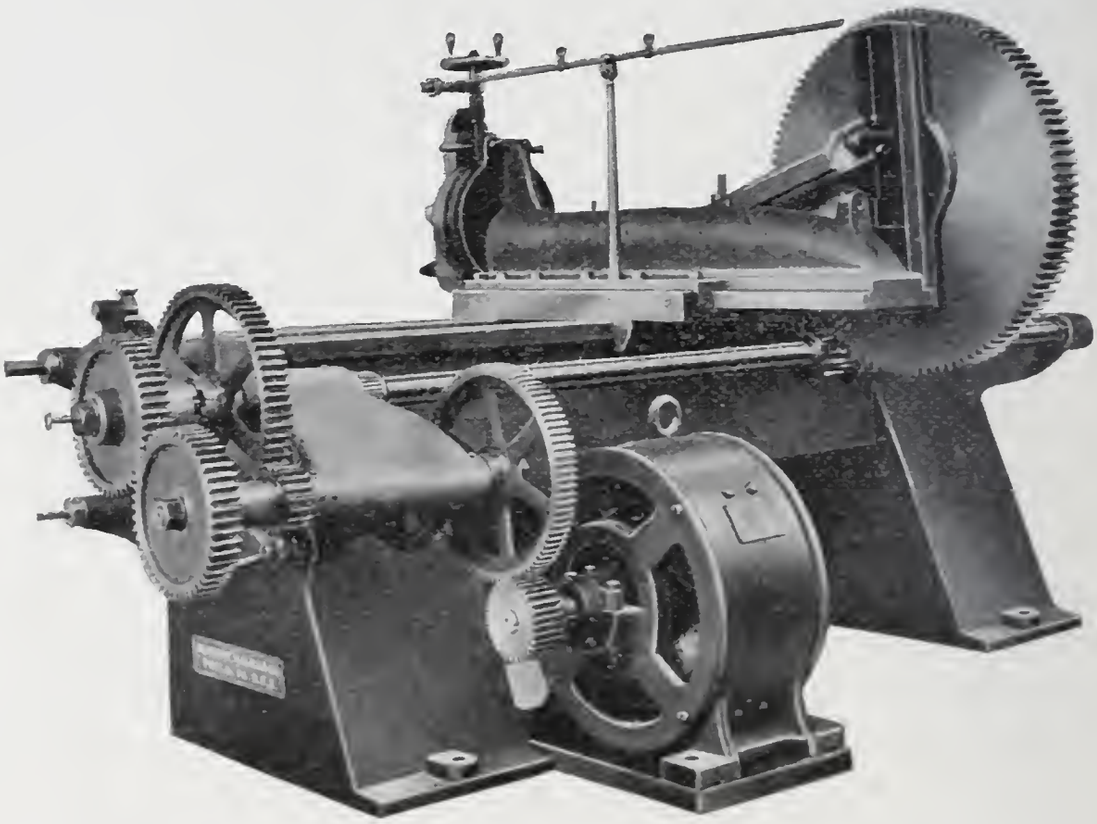
IRON AND STEEL MILLS—

Electric motors of both the alternating and continuous current types have been used for operating nearly all the auxiliary apparatus in iron and steel mills including cranes, hoisting, hauling, transfer tables, shears, punches, saws, cross rolls, straightening rolls, screwing down rolls, roller beds for slabs, ingots and blooms, pouring steel, horizontal charging machines for open-hearth furnaces, etc., etc.

The variable speed motor is used universally for cranes and hauling and generally for screwing down rolls, charging machines, and small reversible roller-beds, pouring steel, etc. The compound type of motor is used for large roller beds and those which are not frequently reversed, for saws, cross and straightening rolls, punches and shears, transfer tables. The motors used for roller beds are generally mounted in pits and covered so as to keep out the dust and dirt.



Compound wound motor operating passenger elevator.



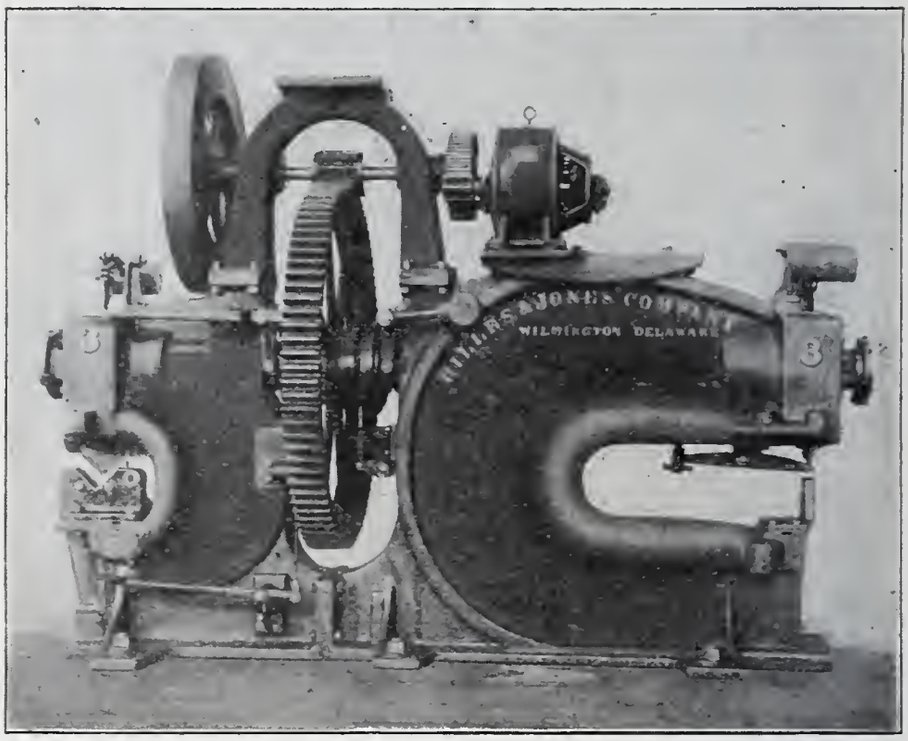
Compound wound motor operating transverse head shaper.

Aside from the auxiliary apparatus, motors are now also being used to drive some of the rolls of steel and iron mills. Eight and a quarter inch rolls at the Remschied Works are driven by 100-horsepower, 225 to 350 r. p. m. motors for rolling tool steel from 1½-inch section bars. 1,200-horsepower compound motors are now being installed at the Phoenix Mills for reversing rolls. A 1,500-horsepower motor has been installed at the Pittsburgh Reduction Co.'s works for several months, and, we believe, it is used for driving blooming mills. Two 1,500-horsepower compound wound, 100 r. p. m. motors, suitable for 25 per cent. increase in speed are now being installed at the Edgar Thomson Works of the Carnegie Steel Co. for rolling rails.

Although motors are now used in a few mills for driving the smaller rolls, it is believed by most mill and electrical engineers that they will eventually be used for driving the entire mills. Mill motors in general must stand intermittent excessive loads and the flexible connection which electric motors furnish between the prime mover and the load will surely prove a great saving in repairs over the steam driven rolls. When the mills have their own generating plant certain variations in line voltage are generally permissible. When large motors are used for blooming mills or similar service it is of great importance, however, to flatten out the current peaks which will develop at overloads such as those produced when bars enter the rolls. A system which will greatly assist in reducing these peaks and is especially applicable for infrequent starting and reversals consists in mounting a heavy flywheel on the shaft of a compound type motor, the motor being so designed that its speed will drop enough at a predetermined overload to allow the inertia of the flywheel to automatically take the overload. By properly designing the motor and flywheel the overload at the motor and power house can be kept within reasonable limits so that no disturbing effect will be felt by other motors on the circuit. In order to get the best efficiency under normal loads when a wound rotor induction motor is used with this system, a resistance is

automatically thrown in the rotor circuit at a predetermined overload, thus lowering the speed and allowing the flywheel to take the overload.

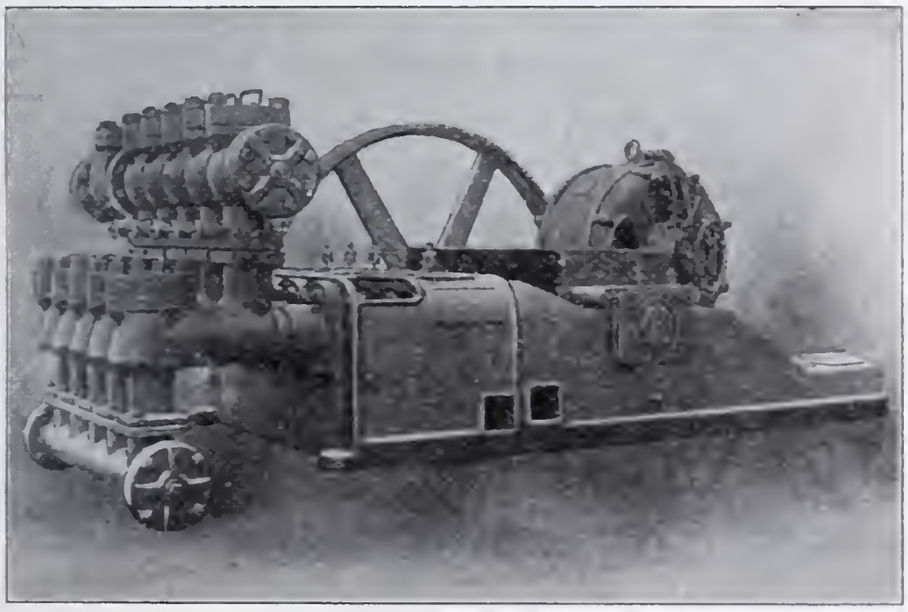
In cases where the voltage regulation of the system from which power is taken must be fairly good, a system similar to the "Ilgner" system which has been used in Germany can be applied. This system is also applicable to hoisting and similar work. The Ilgner system is somewhat similar to the Ward-Leonard system with the addition of a flywheel and consists of a motor-generator set, with a heavy flywheel mounted



Compound motor operating punch.

on their common shaft. The motor can be either alternating or continuous current, having the compound characteristics so that the flywheel will take the overload. The motor is connected directly to the supply circuit. The generator is a compound wound continuous current machine. The shunt field being separately excited from a machine mounted on the motor-generator shaft. The generator current is used for operating a continuous current motor which is connected to the rolls and is excited from the generator exciter. The speed of the motor can be changed by varying the exciting current

of the generator. The efficiency of this system even at low speeds is very good. It can be applied when it is necessary to reverse the rolls, as it is only necessary to reverse the generator field to reverse the direction of the roll-driving motor. The above system is now used for operating 18-inch rolls at the blooming mill of the Bethlen-Falva Iron Works (Germany.) The motor has a capacity of 600-horsepower at 5,800 volts, 50 cycles, 16 poles. The generator (good for 100 per cent overload) has a capacity of 500 K. W., at 510 volt, 300 to 365 r. p. m. The flywheel weighs 20 tons and it absorbs 16,000 horsepower seconds when the speed changes from 300 to 365 revolu-

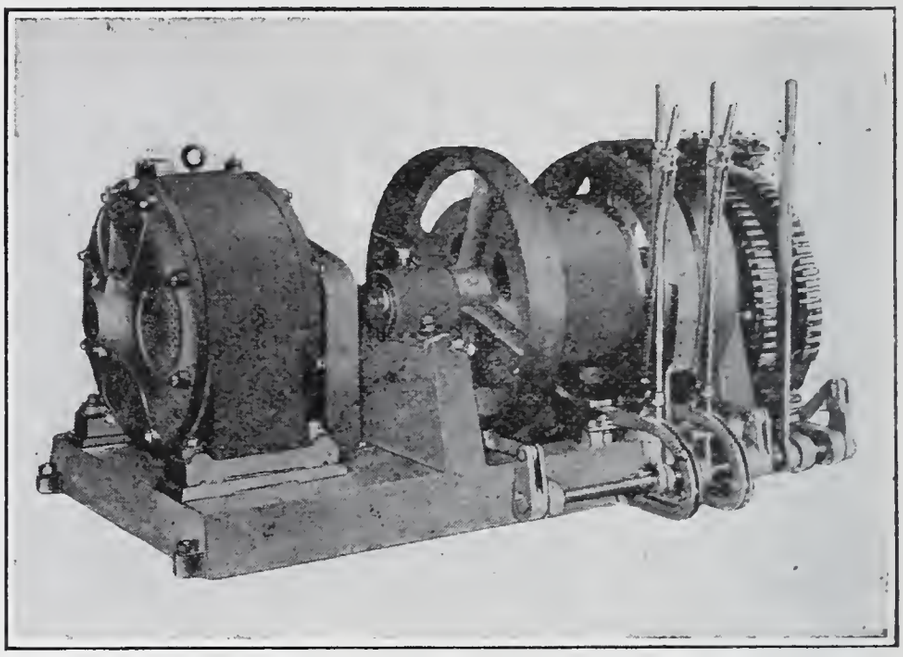


Alternating current induction motor driving a direct-acting pump.

tions. The roll-driving compound motor has 200 horsepower normal and 600 horsepower overload capacity and runs at 60 to 110 revolutions. A 12-ton flywheel is mounted on this motor shaft. The roughing mill has 14-inch rolls and is driven by a motor having the same capacity as the blooming mill motor, but runs at 150 to 230 r. p. m. approximately and has an 8-ton flywheel. It is stated that the load fluctuations at this plant are very small and constant power is taken from the supply mains.

MINING—

The increasing application of the electric motor to mining machinery is due first, to the economy resulting from the centralizing of the power generating stations instead of using isolated steam boiler and engine plants or long lines of piping which are sometimes difficult to place in a safe and convenient place, together with the advantage which can frequently be taken of cheap power from waterfalls; second, to the ease of control and economy and facility of electric transmission for

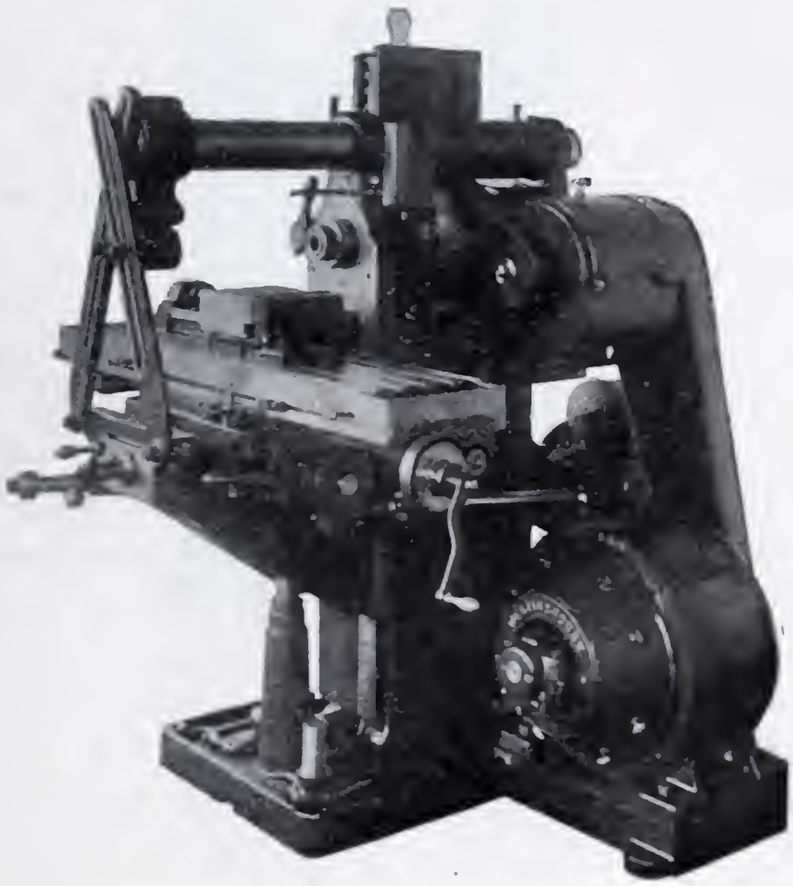


Alternating current induction motor used for mine hoisting.

motors applied to hauling, winding, drilling, cutting, rock-breaking machinery and water pumps, ventilators, fans, etc.

Either continuous or alternating current motors are suitable for driving mining machinery and the kind used will depend upon the cost of power at the mine rather than the characteristics of the motor. In general, if the power is to be transmitted any distance, alternating current would be used, while, if it were not necessary to transmit the power, local conditions would determine which kind of motor to use. As there is no sparking of any kind in the short circuited rotor induction motor it is considered the best suited for use in mines where explosive dust or gases are found. It also is

the simplest, requires the least attention, can be started from a distance, and can be used in places inaccessible for frequent inspection. Continuous or alternating current commutator type motors should be entirely enclosed when used where there are explosive mixtures to prevent ignition of the gases by sparks at the brushes. When motors are entirely enclosed a larger motor must be used for the same rating or an air blast or other means used for keeping the motor cool if the same size frame is used.



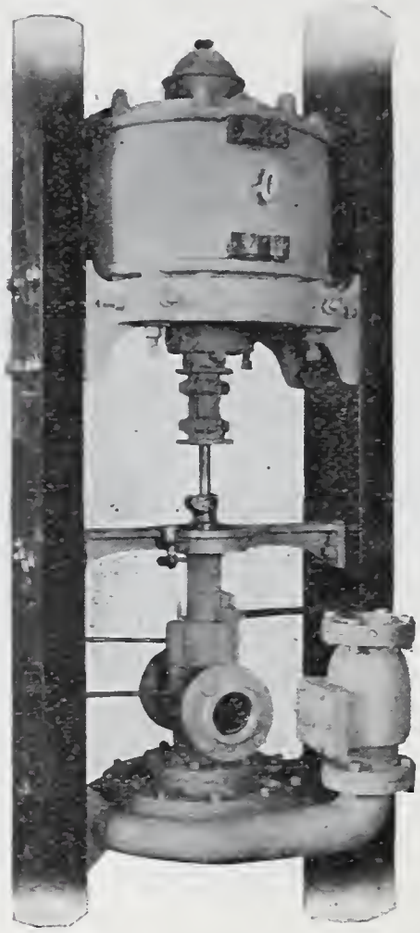
Shunt motor operating milling machine.

Hauling and Hoisting.

Electric locomotives have proven economical in mine haulage and their application to this work especially when the grades are not exceedingly heavy is constantly increasing. The control is simple and easy and they are made for low and narrow entries. The variable speed motor is best suited for this class of work and the series wound continuous current motor has been used more often than the other types, although

the single phase alternating current motor will surely receive its share of the future applications.

For very heavy grades electrically driven drums are now frequently used for hauling and hoisting instead of locomotives. If an endless rope system is used, the drums being driven continuously in one direction, a constant speed or compound motor should be used depending upon the starting torque and amount of load thrown on at any time. If reversing drums



Vertical alternating current induction motor driving a centrifugal pump.

are used, a variable speed or compound motor should be used, depending upon the starting conditions and length of the runs. The series motor should not be used if the load at any time will be small enough to allow the speed to become too great. Both alternating and continuous current motors of the types mentioned above have been used for hoisting and haulage. There are also many special systems of hauling and hoisting

which depend upon the layout of the installation and are too numerous to be taken up in this paper.

Both alternating and continuous current motors are also used in mines for driving centrifugal and direct acting water pumps, air compressors, ventilators, fans, coal cutting machinery, etc. Constant speed motors should generally be used for continuous running fans and either these or the compound type of motors for intermittent running fans. For triplex pumps or pumps which require very nearly constant torque during the entire revolution, constant speed or compound motors are applicable. For single cylinder pumps which require varying torques during a revolution the compound wound motors should be used to keep down the fluctuations in current. A great saving in starting current can be made where motors are required to start up under a pumping head if a by-pass is used for the water until the motor is up to speed. The by-pass should then be closed slowly so as to load up the motor gradually. The insulation of all motors for mine work should be moisture and water-proof.

The electric motor is also used advantageously in placer mining for pumping, hoisting and dredging machinery, conveyors, bucket lines, etc.

DISCUSSION.

Mr. A. Stucki, Mem. Eng. So. W. Pa.—I was always under the impression that the alternating current single phase motor was the motor of the future on account of the ease of transmission. Supposing the generation and the relative design of the motor be of equal standard, the matter of transmission being naturally in favor of the alternating current, wouldn't that make the alternating current the most advantageous one?

Mr. Reed—The operating characteristics of the alternating and continuous current series motors are practically the same and both are suitable for this kind of work. Many of the alternating current motors are designed to operate also

on continuous current. When the generating station is close to a short railway so that feeders and trolley wires are not very long and the trolley voltage is limited to about 700 volts, there would probably be little advantage of one system over the other. But for long inter-urban lines where the trolley voltage is not limited a great saving in the cost of secondary distribution and transmission of power can be made by using high voltage, and where there are frequent starts a saving in the starting energy will result where the alternating current system of voltage control is adopted. For this class of service it is probable that the single phase system will be used. A number of installations have already been made on inter-urban roads and several steam roads are now contemplating the adoption of the single phase system. The New York, New Haven and Hartford Railroad Company have lately decided to equip about 70 miles of their road with this system.

Mr. Samuel Diescher, Mem. Eng. So. W. Pa.—In shops and mills where the motor is not far from the source of power is it more economical to use continuous current?

Mr. Reed—If the distance between the source of power and point of application is very short it would be best to have the generated voltage the same as the voltage required for operating the motors and there would probably be little difference in the cost of transmission of the two systems. The system that should be adopted would then depend upon the class of work for which the motors are intended.

In general, if only constant speed motors were required either alternating or continuous current motors could be used. And if motors giving many different constant speeds were necessary without the use of mechanical speed changing devices the continuous current motors would be more suitable than the alternating current. Under the conditions given whether one system or the other would be more economical would depend upon the class of work required of the motors.

Mr. G. M. Campbell, Mem. Eng. So. W. Pa.—In connection with variable speed motor work, is the alternating current satisfactory for the purpose? Take, for example, poly-

phase induction motors with wound rotor, have they characteristics suitable for variable machine tool work? When the speed is below normal, will the speed remain reasonably constant with a varying load or vary, similar to a D. C. motor with speed reduction by means of armature resistance?

Mr. Reed—The speed of induction motors which use different rotor resistances for obtaining different speeds will change with the torque and H. P. required of the motor. For a given rotor resistance the speed will remain contant so long as the load remains constant, but will change when the load is variable, the speed increasing as the load is diminished and decreasing as the load is increased. This variation in speed for changes in load will be greatest for the maximum resistance of the rotor.

Mr. G. M. Campbell—Very much like the operation of a direct current machine with armature resistance?

Mr. Reed—Yes, very similar operating characteristics. These characteristics may be advantageous for certain classes of work. Such as, for example, the operation of some reciprocating motion tools such as shears, punches, etc., where it is advantageous to have the speed increase as the load is diminished and also to aid in obtaining a quick return motion when the load on the motor is a minimum. When the resistance in the rotor of a variable speed induction motor is increased above normal, the motor will still operate under varying conditions of load as a variable speed motor, the speeds for the same torques being less than those when normal resistance is used.

If the field strength of a constant speed shunt wound motor be changed so as to give a lower speed the motor will still operate under varying conditions of load as a constant speed motor, the speeds for the same torques, however, being lower than those when normal field strength is used. If the field strength of a variable speed continuous current motor be increased it will still operate as a variable speed motor whose speed for the same torques is less than when normal field strength is used.

Mr. G. M. Campbell—Mr. Reed mentions that an inter-

polar D. C. variable speed motor of a certain capacity could be used with a smaller frame than a standard motor. In general, manufacturers sell their motors by the size of the frame. Should not, then, an interpolar variable speed motor for the same capacity sell at a considerably lower price, and, if so, why are they not more used?

Mr. Reed—The limit to speed variation in a continuous current shunt motor is the commutation at high speeds when the field strength is weak. The interpolar motor gives a constant commutating field strength and permits a much greater variation in speed with a given frame than the ordinary motor does.

The reason more of these are not used is because they have only lately been developed in America. They have been used in Europe for some time.

Mr. Stucki—Supposing like conditions, a short transmission, the same horsepower, etc., and that we have the choice between a continuous and an alternating current, which of the two motors would be the most expensive one?

Mr. Reed—In a general way with the comparatively new single phase alternating current series motor, the cost of the installation, assuming that the cost of transmission is the same, would be practically the same for alternating and continuous current motors.

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PAUL KREUTZPOINTNER,
Non-Member.

With expressions of sincere appreciation for the honor accorded me to address this meeting of Pittsburgh engineers, I beg to assure you of the heartfelt pleasure it affords me to speak to you of the work, value and aims of the American Society for Testing Materials, a society which has become and is destined to become still more, an important factor in the technical-economic fabric of our country.

Apparently the society, being exclusively composed of technical men, serves purely technical purposes. But since the work of the society results in the conservation and economic application of the resources and energies of our country and since the resources and energies of a country are the basis of all industrial activity and since industrial activity promotes material prosperity, and further, since material prosperity, present and future, fosters physical well being and mental contentment with a consequent higher standard of civilization and ethical life, therefore the American Society for Testing Materials not only satisfies the demands of the engineer for purely technical knowledge, but it also fulfills an important economic and ethical function because of the intimate relation of the work of the society to the mental and material welfare of the people through the judicious use of our national resources. This relation between the technical work and the economic aspect of the society explains the rapid growth of its membership.

*Meeting of the Structural Section, September 26, 1905.

All industrial activity has for its object the production and distribution of goods for the purpose of satisfying the needs and wants of the people and since the engineer, of whatever description, has become the ruling and guiding spirit in the use and application of the technical processes whereby food, shelter and clothing is produced and distributed in the necessary quantity and quality, it is the engineer's function to produce the largest possible quantity of goods of maximum quality with the least expenditure of the country's resources, energy and time. The engineer who is not able to do so will soon find himself out of a job nowadays, or if he is in public service and allows himself to be a wasteful servant of the people's interests, then he violates his trust as an engineer who, by virtue of his scientific and technical knowledge has become the guardian of the economic, and through that the ethical welfare of our country and as such largely influences the weal and woe of the people.

The aim and end of all social and political economy is to create a state of mental satisfaction, happiness and contentment of human beings who become subject to the influence of economic measures and processes.

However, advancing civilization has given us the ability and knowledge to make use of the laws of nature, or science, to our advantage and by means of that knowledge in turn to use our resources economically. The engineer, by virtue of his scientific-mathematical training has control of that knowledge and therefore the engineer plays the most important part in the economic and through that in the ethical life of the people and the advancement of civilization. It should therefore not only be the aim of the engineer to equip himself for practical life with an efficient scientific-mathematical knowledge, but also with a broad and deep comprehension of the economically important and ethical value of his work and its relation to the welfare of the nation. In all his many-sided activities it is the engineer's endeavor to make use of all factors of production and distribution with the least expenditure of time,

money and material, being careful, however, that this economy is not carried to the point of injury, and since this economic result of the engineer's technical activity, with its consequent ethical well-being of the nation, can best be secured by unity of action, by co-operation, by uniformity of the means and methods of the materials applied in the production and distribution of food, shelter and clothing, other things being equal. Looked at from this standpoint we can see the value, to the engineers, from a technical standpoint and to the country from an economic standpoint, of the American Society for Testing Materials whose aim and object it is to find out not only what materials are best adapted for a given purpose, but also to devise methods and how to apply these methods to attain satisfactory results.

In other words, by the co-operative study of the properties and qualities of the materials of construction and by devising and perfecting means and methods how to do this, thus securing needed uniformity, the engineer is enabled by the help of the society to produce and distribute the largest quantity of goods of maximum quality with the least expenditure of the countries' resources and energy. But with advancing civilization and complexity in the conditions of life further demands will be made upon the scientific-mathematical knowledge of the engineer and the use of the materials of construction and means of distribution.

Civilization will use the available materials of construction and consumption according to the prevailing mental attitude among the people of a given country of what is best for the people for the time being.

Our present methods of testing materials are not a creation but a growth. The first engineer was probably a savage who conceived the idea of fastening a sharp stone to a stick in order to get more power than he could by using it with his hand alone. He undoubtedly used sinews for tying that stone to that stick, and in some way tested the strength of these sinews. And from that time on there has been a slow evolu-

tion in the means and methods of ascertaining the qualities of materials.

The Romans had a large factory for the fabrication of arms, with a large arsenal at Salorum, as early as 205 A. D. Undoubtedly they had means of ascertaining the qualities of materials in their wars with the Gallic tribes, who used long heavy swords which were quite formidable to the Romans. They soon found that these long swords were of very soft iron, and by making their armor hard these long swords were bent by each stroke and had to be straightened out again before another stroke could be made. The Romans had six arm factories in Italy, three or four in the English islands, two in Spain, and others in other parts of the Roman possessions.

During the Middle Ages when the sword was the most priceless possession in a freeman's family, when it was solemnly baptized with a name, when it was taken to church and consecrated by the priest with holy water, they had means of ascertaining the qualities of materials. And the Guilds in the Middle Ages, while they had not the accurate scientific knowledge of today, had yet acquired through generations of observation a very large amount of empirical knowledge which today underlies our scientific work to a very large extent.

These Guilds considered it the highest point of honor to furnish the best material that could be furnished and the most perfect work that could be made by their skill, and for that reason they devised ways and means of ascertaining qualities of materials. Gold and silver was made according to certain grades, sixteen being the fundamental division of parts or "grades" for silver, and twenty-four, called "carats" for gold. Inspectors were chosen, and only the most honorable members of the Guild were elected to this office. And I may say that the methods sanctioned by the Guilds for testing underly in Europe today much of the restrictions devised by the various governments to guide the engineer in his work, and for that reason European engineers are more restricted in their action than American engineers.

Because of the necessity of ascertaining qualities we find very early attempts made for more scientific testing. For instance, we have Perault's investigations in 1680 on the physical qualities of metals; Robert Boyle, in 1675 estimating the specific weight of iron and other metals. Reamur published his memorable work in 1722 on the structure of steel and iron, its elasticity, strength, hardening qualities, etc. He invented case hardening and malleable iron. He used the microscope for the examinations of metals and made drawings of their microscopic structure. Swedenborg, in 1834, explained the making of wrought iron from cast iron, and of testing iron, and Reamur had before that a testing machine for testing wire in different ways. As early as 1710 he used a testing machine of simple construction. Gazeron and Reineman in 1772 investigated the elasticity of metals. The Frenchman Saufflet in 1781 and Sickingen in 1782 worked on the line of the properties and qualities of iron and steel. Bramah, a machine builder, and Banks, a bridge builder, wrote very interesting and instructive practical works on the qualities of metals used by them, in 1803. Karsten, whose name occupies one of the foremost places in the history of metallurgy, in 1804 determined the shrinkage of cast iron, and Thomas Young in 1807 determined the modulus of elasticity. Tregold, whom you well know, in 1810 determined the strength of cast iron and also made experiments so fine that he measured the elasticity of metals to the 1200th part of an inch. Telford in 1817 and Rennie in 1818 also elaborated upon the means of determining the strength of iron and steel. Barlow in 1814 made very elaborate investigation of the strength of timber. Rondeley in 1814 wrote largely on the properties of metals. Dulcan in 1820 produced methods of systematic testing. Seguin in 1824 wrote on the strength of wires, and Sagerhjelus in 1825 wrote a treatise on the strength, malleability, elasticity, density and uniformity of iron.

These investigations form what we may call the historic part of our present methods of testing. When we come to the

present time we may begin about fifty years ago. The American Hodgskinson in the latter part of the 40s and the beginning of the 50s determined the qualities of cast iron, producing very valuable results. Vikers in England in 1861 determined the relation of carbon to strength. Kirkaldy in 1862 established the first testing department. Knut Styffe in 1867 investigated the effects of low temperature upon iron and steel which was epoch-making in its time and still serves largely as the fundamental information in that line.

Fairbairn produced the first testing machine, and I can remember when Fairbairn machines were still used in this country.

Then we come to Woehler's investigations which form the foundation for our present knowledge of fatigue and elasticity in metals. He began his work in 1857 when he was an officer in the Prussian Railway. He published his findings in 1860 and up to 1875. Woehler's law is that repeated stresses, although not carried near the point of fractures, will produce rupture. That is, a stress just a little beyond the elastic limit, but not sufficient to produce rupture, will produce microscopic fracture, and this will form a new elastic limit, and the repetition of these small stresses will produce what we call detail fracture. This has a very peculiar appearance and sometimes we may be able to find as high as twelve to sixteen such detail breaks.

Then in the early 70s Sorby began his microscopic investigations of the structure of metals, and at the same time Martens began a similar investigation independently and without knowledge of Sorby's work.

In 1876 the cement manufacturers began to establish specifications of their own. Then in 1879 the German government officers, on the basis of Woehler's findings, established specifications for railroad materials. These specifications called for strength plus contraction of area must give a factor of 100. The manufacturer found that it was possible to produce inferior materials under these specifications, and that

contraction of area was erratic and not a fair test, and to protect themselves they went together in 1881 and had investigations made on the relation of contraction of area to quality. This dissatisfaction of the manufacturers and their consequent association was the beginning in a systematic way of the present work of the International and American Societies for Testing Materials.

In 1882 there was an informal meeting between the chairman of this manufacturers' committee, Bauschinger, Martens and a few others, but the first official meeting was held in Munich in 1884, with Bauschinger as chairman. The second Conference, as they were called, was held in 1886 in Dresden; the third in 1890 in Berlin; the fourth in 1893 in Vienna; the fifth and also the first International in 1895 in Zurich. From 1886 the meetings became more and more international in character, the French attending as guests in 1890 and 1893, the American Society of Mechanical Engineers being represented in 1893, the United States Army in 1895 and the Navy in 1897. Previous to the 1895 meeting Germany, Russia, Austria, Switzerland and Denmark had formed what was called the National Society for Testing Materials.

In this country the first few members formed themselves into an auxiliary or section of the International Society in 1896, and had their first meeting in Philadelphia in 1898 and have had regular meetings since. Until 1902 it was affiliated with the International Association as a section; but in 1902 a charter was taken out and the American Society for Testing Materials was formed.

Now you will perhaps inquire what has been accomplished by the American Society. To some extent the society has drifted away from the methods of work of their European brethren, not through any lack of appreciation of the value of their work, but simply through our different conditions of development. In Europe the engineer is not as free to change specifications as is the American engineer. For instance, Woehler's specifications based on strength plus contraction

was thought not to be a reliable measure of quality in commercial testing. Sufficient pressure was brought on the Prussian government to have a committee appointed consisting of three members of the Engineer's Society, three of the German Manufacturers' Association and three government railroad officers, and this commission gave seven years of careful investigation to determine how much value there was in Woehler's specifications. This committee, with Woehler as its chairman, came to the conclusion that contraction of area follows no law of proportionality to the extent as elongation is proprotional to strength and recommended the abolition of these specifications. However, if the writer is rightly informed, they were never officially abolished, but simply became obsolete through lack of attention.

The American engineer is not hampered in this way. As a result of this I know a time when there were hanging on the walls of our manufacturers ten different specifications for doing exactly the same work. I know a tire mill that had 128 sets of rolls where 30 sets would have been entirely sufficient to do the work. Railroads had to carry from 30 to 35 different car couplers when two or three would have been all that were necessary. Now the first thing we had to do in this country was to get a recognition of the fact that certain uniform laws underlie phenomena of stresses and strains, and the American Society has succeeded in bringing about a recognition of this fact. We have succeeded in bringing about a recognition of the correctness of Barba's law that geometrically similar test sections of the same metal will have their form changed geometrically similar when the same stresses are applied under the same circumstances, and today all over the country we have uniform test sections. We may differ as to the real scientific value of that, but we do not in the first place know the properties of metals sufficiently thoroughly that there could not be an honest difference of opinion on some points, and secondly, in the commercial testing which comes now under our consideration, the commercial factor of lee way is con-

sidered. That is to say, the unavoidable slight error in commercial testing, due to a difference of testing machine, measuring at different places, and so forth, is offset by the unavoidable differences of quality in commercially produced materials.

An immense amount of work has been done by the American Sociey of Mechanical Engineers. Early in the 80s a committee was formed to recommend uniform testing methods. This committee worked several years and in 1889 presented their findings to the Cincinnati meeting. But that society did not proceed farther in a general investigation because it was soon found that owing to our rapid development no one society was large enough to satisfy the demands of all the various engineers as they became specialized in their work through our industrial activities. But I delight to give credit for the very faithful and valuable work of that society.

Having gone thus far in showing what has been done, the next question is what will be done and what should be done in the future for the benefit of the engineer.

The society having attained its first necessary object of standardizing and unifying methods for investigating, inspecting and testing the question arises what next. He who ceases to go up begins to go down. He who is satisfied to adapt himself to environment will soon fall behind because environment is changing and the progressive engineer must possess the mental power, the scientific knowledge, the mechanical skill to be able to change his environment in anticipation of the changing conditions of life. What are the main factors in changing the condition of life in the United States? These factors are the increasing density of population and decreasing quantity, or quality, of our natural resources.

With increasing numbers in population the available resources and their products will have to be subdivided, will have to be cut into smaller portions, as it were, to provide the necessary food, shelter and clothing for the growing multitude of people. The stores of raw material, ores, coal, lumber, min-

erals of all kinds, which form the basis of industrial activity will diminish in quantity or quality, or both, and means and methods will have to be devised, and thanks to our scientific knowledge and engineering skill, are beginning to be devised, to make the inferior quality raw material do the same service as those of superior quality did, and to husband the resources still left, in such a way that they may last as the basis of future material prosperity the longest possible period of time. It is well known and admitted that at the present rate of consumption the available stores of best ore in the Lake Superior region will be exhausted in 50 years. There are more than 2,000 diamond drills at work to find new ore bodies, but thus far the indications are that the present ore beds will not be duplicated. And so it will be with all other raw materials of the mineral kingdom. They will become scarce, more expensive to mine, longer distances to be hauled, more difficult to be turned into useful products. This does not mean cessation of industrial activity and starvation, but it means that in the future, and the near future at that, the engineer, the technical man, will be called upon to become an even more important factor in the economic life of the nation because he will be expected to find ways and means to feed, house and clothe the multitudes of people and keep them satisfied and contented under the problem of increasing cost of production. Then the engineer will look to the American Society for Testing Materials as his friend and guide in the hour of need because the large membership and varied experience in all lines of engineering practice of its members, their occupations in production, consumption and transportation, the aggregate high standard of scientific-mathematical knowledge and technical skill represented and the co-operative spirit prevailing in the society and because of the mutual interest which every member feels in the success of the society which, in turn, will promote the interest and success of each individual member. This combined knowledge, experience, expertness and co-operative spirit will then become available to solve the technical prob-

lems of the increasing technical and economic perplexities of density of population and diminishing resources by united research work into the realm of nature and applied science.

Every candid engineer will admit that we do not yet know all about the structure, qualities and properties of metals, minerals and fuels.

The nature of strength, plasticity and elasticy of metals, their relation to each other and their function in determining the life of a structure are still largely unknown quantities, although we know a good deal of the qualities of materials and their application for specific purposes. Then with diminishing resources comes not only the question of greater economy in the use of all classes of materials, but how to make inferior material do effective work and to find suitable substitutes for substances which have become too costly for the average consumer, as for instance in the line of building materials and fuels, the effectiveness and economic value of which will have to be determined by the united wisdom of the engineer, because the learning of the single individual is no longer sufficient to cover the auxiliary knowledge necessary to successfully carry on a special line of activity. This necessity for joint action and the freest exchange and interchange of ideas and experience explain the rapid growth of our society more than anything else.

There is evidence that the scope of this further scientific-economic activity of the American Society for Testing Materials is being recognized and an answer given to our question what next. At the last annual meeting of the society the following suggestions were offered:

"Standard specifications for structural steel for bridges; for steel rails, for steel castings, for steel axles; for steel forgings; standard tests for road materials; standard specifications for cement; reinforced concrete; uniform speed in commercial testing; the effect of heat upon the crushing strength and elastic properties of concrete; influence of methods of piling stay-

bolt iron on vibratory tests;" and a great number of others which time will not permit to be enumerated.

These suggestions are not only indications, but, together with the work of some of the committees, are beginnings of the higher standard of work the society is going to do, is compelled to do, to meet the problems of the complexities of life the engineer will have to solve for the good of himself and his fellow men.

In conclusion I take the liberty to point out another factor in connection with the national economic importance of the Society for Testing Materials.

The political power of a nation and its ability to defend its interests is proportional to that nation's industrial and commercial activity. Industrial and commercial activity are at once the cause and effect of political power and ability for offensive and defensive national action. By the development of a country's resources, industry and transportation, material wealth and the agencies are created to demand and compel respect of national action and to extend protection to life and property, to its citizens and commerce. With the decline of a country's industries and the exhaustion of its resources begins the decline of its political power and influence. This has been so ever since the Phoenicians traded along the coast of the Mediterranean and the United States will be no exception to that rule.

Indeed, our present political power and supremacy is the direct outgrowth of our industrial and commercial development and since the engineer has had the largest share as a creative agency in that industrial development and incidentally was thus instrumental in the creation of our national power and commercial supremacy, and since these results could not have been achieved without the engineer investigating and testing the materials of construction for their usefulness so that these materials may be applied economically and further, since this investigating, testing and applying economically of the materials of construction will be of still greater import-

ance in the future in order to preserve and continue our political power, national supremacy and a high degree of culture and civilization, and since the American Society for Testing Materials is an active agency in the hands of the engineer to achieve this worthy aim, we can readily see that the work and aim of the society is of vital national-economic importance.

And now, gentlemen, I take the liberty to cordially invite those of you who are not members of the American Society for Testing Materials to become members. The engineers of Pittsburgh represent a community of interest and a community of interests requires a great number of points of contact in order to be successful and these you will find in our society in the interest of yourself and in the interest, and for the greatness and grandeur of our beloved country.

OFFICERS FOR 1905.

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Treasurer, A. E. FROST, Secretary, F. V. McMULLIN.

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Reception Committee.
C. Ludlow Livingstone, Chairman.
M. C. Blest, C. H. Gisin,
C. R. Branson, F. D. Purdy.

STRUCTURAL SECTION.

E. K. Morse, Chairman.
R. A. Cummings, Vice-Chairman. T. J. Wilkerson, Secretary.

Directors.
T. D. Lynch, Francis S. Rice.

PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

VOL. XXI NOVEMBER, 1905 No. 8

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The 258th regular monthly meeting of the Engineers' Society of Western Pennsylvania was called to order in the lecture room of the Society's House, 410 Penn avenue, Pittsburg, Pa., Tuesday, October 17, 1905, at 8:15 P. M., President Samuel Diescher in the chair, with 40 members present. The following members registered:

Geo. T. Barnsley,
A. C. Beeson,
G. M. Campbell,
J. W. Cruikshank,
R. A. Cummings,
G. H. Danforth,
Charles Davis,
E. H. Haslam,
F. R. Jennings,
E. V. D. Johnston,
Thos. H. Johnston,
Harry J. Lewis,
Robt. Linton,
C. Ludlow Livingston,
F. V. McMullin,
A. E. Myers,
Geo. W. Schluderberg,
A. Stucki,
E. J. Taylor,
Willis Whited,
T. J. Wilkerson,
F. W. Winter.

The minutes of the last meeting were read and approved. The President announced the death of Mr. Frank C. Emery.

The Board of Direction reported that hereafter the Secretary will draft obituary notices.

The report of the Board of Direction was read recommending for membership four applicants.

On motion the Secretary was instructed to cast the ballot of the Society for the election of the applicants recommended by the Board.

Mr. Barnsley of the Committee on New Quarters reported that by the next meeting he hoped to be able to present something definite on this subject.

The Chairman announced the appointment of the following Committee on Nominations: Charles F. Scott, Chairman; Morris Knowles, Robert A. Cummings, James O. Handy and Ralph Crooker, Jr.

On behalf of the Reception Committee, Mr. Barnsley announced that an excursion would be given by the McIntosh-Hemphill Co., to South Sharon, on October 28th, leaving Union Station at 12:30 P. M.

A paper on "Centrifugal Fans" was read by Thos. H. Johnson.

After discussion the meeting adjourned at 10:15 P. M.

F. V. McMullin,
Secretary.

NEW MEMBERS.

NAME.	OCCUPATION AND ADDRESS.	ENDORSED BY
ARTHUR H. ANTHONY,	Ass't to the Supt. Construction Dept., National Tube Co. h. 551 Shaw ave., McKeesport, Pa.	Geo. T. Snyder, Alex L. Hoerr, W. A. Cornelius.
JOHN P. BLAND,	Technical Adviser, "Daily Mail," London. h. 285 Leonard st., Peterborough, Northamptonshire, Eng.	Richard Khuen, P. Bryn, J. K. Lyons.
ACHILLE DREYFUS,	Manager, Royal Metal Steel Co., 17 Bridge st, New York.	Harry H. Anderson, A. Stucki. Chas. S. Foller,
DANIEL H. LITTELL,	Vice President, Expanded Metal Fire Proofing Co., 541 Wood st., Pittsburgh, Pa.	J. F. Kuntz, W. M. Judd, W. O. Abbott.
CHARLES S. PARSONS,	Draftsman, Colonial Steel Co., Pittsburgh, Pa, h. 1305 3rd ave., New Brighton, Pa.	Frank S. Jackson, Geo. T. Barnsley, Walther Riddle.

MONTHLY MEETING OF BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at the Society's rooms, 410 Penn avenue, Pittsburg, Pa., Saturday evening, October 14, 1905, at 8:15 P. M.

Present: Messrs. Diescher, Flanagan, Lyons, Whited, Knowles, and Secretary.

The following resignations were accepted:

Louis L. Banks,	Edward Schenk,
Harry W. Champion,	O. G. Schultz,
Ellis J. Hannum,	F. C. Weber,
Charles C. Newton,	Arthur J. White.

Treasurer's report:

Building Fund	$1,353.36
Dormant Fund	3,789,93
Checking Account	3,868.13
Total	$9.011.42

Secretary's report:

Membership October 14, 1905	946
Collections Sept. 16th to Oct. 14th, 1905	$ 642.60
Previously reported	7,971.10
Total, 1905	$8,613.60
Total, Oct. 14, 1904	$5,881.18
Increase, 1905	$2,732.42
Payments to October 14, 1905	$6,425.69
Bills were paid aggregating	178.48

The President was authorized to appoint a committee of five members to draw up a new Charter and By-Laws for the Society and report to the Board not later than the December meeting.

The President was authorized to execute a contract with

Percy F. Smith to print the Proceedings at a price of $1.50 per page for 1,000 copies and $4.00 per 100 for "overs."

On motion it was decided to join the American Society for Testing Materials.

On motion, adjourned at 10:00 P. M.

F. V. McMullin,
Secretary.

SPECIAL MEETING OF BOARD OF DIRECTION.

A special meeting of the Board of Direction was held October 25, 1905, at 410 Penn avenue, Pittsburg, Pa., at 8:00 P. M., for the purpose of acting on the recommendations of the Finance Committee regarding investment of the Society's funds.

Present: Diescher, Kintner, Lyons, Barnsley, Knowles, Frost, and Secretary. Also Mr. Carmack, of the Municipal Securities Company.

One $1,000 5 per cent. bond of the Butler Water Company, was ordered purchased out of the Building Fund at 102½ and accrued interest.

Two $1,000 Manufacturers Light and Heat Company's first mortgage Collateral Trust 6 per cent. gold bonds at 101 and accrued interest, two $1,000 Connellsville Water Company, 5 per cent. bonds, at 102½ and accrued interest, and two $1,000 Portsmouth, Berkeley & Suffolk Water Company, of Portsmouth, Virginia, 5 per cent bonds, at par and accrued interest, were ordered purchased out of the Permanent fund.

The name of the Dormant Fund was changed to the Permanent Fund and the Treasurer was authorized to transfer $2,354.52 from checking account to Permanent Fund.

On motion adjourned at 10:00 P. M.

F. V. McMullin,
Secretary.

CHEMICAL SECTION.

The regular monthly meeting was held in the Society house, 410 Penn avenue, Thursday evening, October 19, with the Pittsburg section of the American Chemical Society.

The Chairman and Vice-chairman being absent, the meeting was called to order by the Secretary at 8:40. Mr. J. M. Camp was elected temporary chairman. Twenty-three members and visitors were present.

Dr. F. C. Phillips, Chairman of the Committee on the Estimation of Antimony in the Presence of Tin, presented a preliminary report. He called especial attention to the great desirability of active assistance on the part of members and urged that members who had not yet done so would obtain samples of the alloys in use from him and analyse them. Without such aid he felt that the value of the final report would be greatly lessened.

The business of the evening was the reading of a paper on "The Use of Ammonium Persulfate in the Determination of Chromium in Iron," by Mr. H. E. Walters. The paper was discussed by Messrs. C. H. Rich, F. C. Phillips and the Chairman

On motion the section adjourned at 10:00.

HARRISON W. CRAVER,
Secretary, C. S.

MECHANICAL SECTION.

The regular monthly meeting of the Mechanical Section was held October 3, 1905, at 8:15, with H. H. Anderson in the chair, and 27 members and visitors present.

Mr. Livingstone reported that ten had been present at the dinner before the meeting.

Mr. G. M. Campbell read a paper on "Machine Shop Practice." Discussion was participated in by Messrs. Freed, Anderson, Stucki, Baker, Neilson, Moore and H. M. Wilson.

Meeting adjourned at 10:00 P. M.

H. D. James,
Secretary, M. S.

STRUCTURAL SECTION.

The regular monthly meeting of the Structural Section of the Engineers' Society of Western Pennsylvania was held in the Society house, 410 Penn avenue, Pittsburg, Tuesday evening, October 24, 1905, at 8:30 P. M.

The meeting was called to order by Chairman Morse, 32 members and visitors being present.

Minutes of the previous meeting were read and approved.

There being no Committee reports, unfinished business or new business the Chairman then introduced the speaker of the evening, Mr. Richard J. Donovan (non-member), who read a paper on "The Uses of Steel for River Transportation."

The discussion was taken part in by Messrs. Haggart, Blodgett, Morse, Stucki, Moren, Affelder, Jennings and Judd.

The meeting adjourned at 9:30 P. M.

T. J. Wilkerson,
Secretary, S. S.

FRANK C. EMERY.

Frank Charles Emery was born October 13, 1868, at Maroa, Ill. He attended the Maroa public schools, and after leaving there completed his education at Racine college and the University of Illinois. After leaving college he entered the service of the Illinois Central railroad, leaving them after several years' service to enter the employment of the Baltimore & Ohio railroad, and in 1898 taking a position with the Pittsburg Locomotive works. In 1900 he entered the service of the Westinghouse Machine Company and had risen, by successive steps, until at the time of his death he was in charge of the turbine blading department. He was noted as a mechanic of great ingenuity as well as a forceful character, and was about to be advanced to a position of still greater responsibility when his career was so suddenly terminated.

He was an ardent lover of nature, and took a special delight in photography, being one of the best known amateurs in Pittsburg. His home was filled with many evidences of his artistic skill.

He was married July 25th, 1894, to Miss Anne North, of Wheeling, W. Va., who survives him. There are no children.

While a student at Racine college he united with the Protestant Episcopal church and retained his membership to the time of his death.

He joined the Society in June, 1903, and was one of the most familiar figures at its meetings and excursions. He will be especially missed from the meetings of the Mechanical Section, which he always attended and from which he always claimed to get the greatest benefit and enjoyment.

In the early part of 1905 he had a very severe attack of rheumatism, which laid him up for several months. He had recovered sufficiently to resume his work at the Westinghouse works when, on July 31st, he was stricken with typhoid fever, and in his weakened condition could not resist the disease, and died in the afternoon of August 11th. Interment was at Woodlawn cemetery, Wilkinsburg.

*CENTRIFUGAL FANS.

THOS. H. JOHNSON,

Member Engineers' Society of Western Pennsylvania.

In the course of professional duties it recently devolved upon the writer to make a special study of the ventilation of tunnels, which at once brought him in contact with the subject of fans. In pursuit of knowledge on this subject it soon became apparent that the technical literature in English is very deficient in this respect, and the research had to be carried farther afield, with the result of coming upon one or two points in the designing and construction of fans which seem worthy of being called to your attention.

Murgue's "Theory and Practice of Centrifugal Ventilating Machines," translated by Steavenson, deals with the general relations between *diameter, speed, pressure, volume* and *power,* but does not treat of the details of the fan itself.

Beard's "Ventilation of Mines," in addition to the general relations just mentioned, makes certain statements as to *size of eye, number, width and shape of blades,* without any attempt to demonstrate the governing principles, or to show mathematically how variations in these details affect the efficiency of the fan. We quote as follows, page 73:

"The number of fan blades is somewhat dependent upon the size of the fan. There should be as few blades as is consistent with keeping the contained air pressed forward. For all ordinary sizes *eight* blades make a good number, but when the distance between the blade tips exceeds *ten* or *twelve feet* we should begin to increase the number of blades."

And also page 75:

"We give our verdict in favor of the straight paddle blade, except as the inner edge of each blade should be curved forward in the direction of motion."

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*Meeting of the Society, November 19, 1905.

There are a number of other books intended for the use of Mine Foremen and Superintendents, which treat of this subject in a perfunctory way, but afford no assistance in our search for governing principles. Some of them take the form of questions and answers, reminding one of the "Catechism" which some of you remember as a torment of your youth. One of these, a pretentious book of 1140 pages, devotes as many as *three* questions and answers to this important subject.

Perhaps the best practical summary of the subject, as treated by English and American writers, is found in the "Coal and Metal Miner's Pocket Book," compiled and issued by the "Collier Engineer Co.," Scranton, Pa.

It says, p. 392, "The number of blades depends on the size of the fan. An increased number strengthens the fan's action at the circumference by supporting the air at that point, and preventing backlash, or re-entry of air into the fan, due to eddies occuring at the circumference when the blades are too far apart. In general the distance from tip to tip of blades on the circumference should be from *two to three times the depth of the blades.*

And again, "The Guibal blade radial at the top, and curved forward at the base, seems to be most effective. (The *italics* in these quotations are ours.)

In France they have outstripped us in the study of the subject. In 1878 Mr. L. Ser published in the "Memoires de la Societe des Inginieurs Civil" a paper on the "Theory of Centrifugal Fans," which he later embodied in his extensive (3 vol.) treatise on the "Production and Utilization of Heat," published at Paris in 1888.

This beautiful and complete mathematical analysis has not, to my knowledge, been reproduced in English, and hence English and American Engineers have been left a fourth of a century behind their brethren of the Continent.

Mr. Ser is not the inventor of a special form of fan. His paper is a mathematical study of the principles governing the movement of air into and through the fan, and the influence upon that movement of the number, size and shape of the vanes, form and dimensions of the casing, and other details.

Fans designed in accordance with these principles differ in certain respects from other types designed under imperfect knowledge of fundamental principles, or following only empirical rules and precedent. Fans so designed in accordance with Ser's theory and formulae have been designated abroad as of the "Ser type."

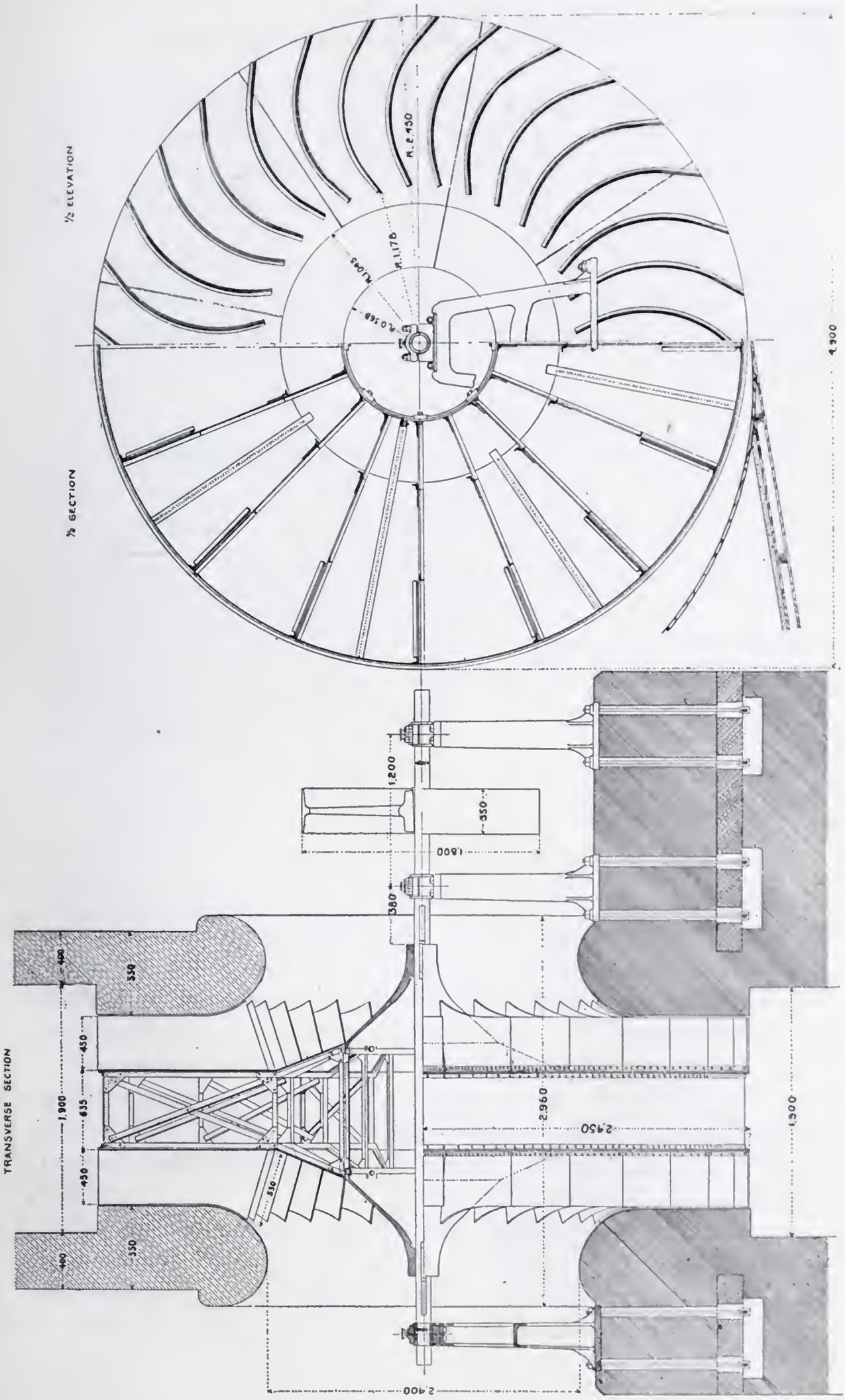
In 1894 the Italian Government appointed a Commission to make a thorough study of the system of artificial ventilation of tunnels proposed by Mr. M. Saccardo, which consists in forcing, by means of fans, a current of air through the tunnel from one end to the other. This Commission set up an experimental plant, equipped with self-recording instruments of observation, at the Pracchia end of the Appennine Tunnel, on the line between Florence and Bologna. The fan installed for this experimental work was designed by M. Saccardo in accordance with the principles established by Ser. Its form and construction are shown in the plate, page 393.

You will note how radically it differs in number and form of blades from the rules laid down by Beard and others. Instead of 8 to 12 blades spaced 10 to 12 feet from tip to tip, or two or three times their depth, there are 32 blades spaced on the circumference only about 1.5 feet or one-third their depth. Also the blades are not radial, but curved so as to incline forward at both top and bottom. There are also some structural features which will be considered later.

The function of a fan is to deliver a required volume of air at a required pressure. Having in mind the old maxim about "the proof of the pudding," etc., we will compare the recorded performance of the Pracchia fan with those of some Guibal fans cited in Kent's "Mechanical Engineer's Pocket Book," p. 522.

There is no disagreement among the different authorities as to the laws governing the pressure, in its relation to diameter and speed, and we will confine the present inquiry to a comparison of the volumes of air delivered.

The fans are compared on two separate bases: 1st. The ratio of the volume of air delivered to that of the solid of revolution generated by the blades; that is to say, the number



FAN AT THE PRACCHIA END OF THE APPENNINE TUNNEL.

of times the fan empties itself in each revolution. (Experiments show that for the same fan, with constant area of outlet, this ratio remains constant at all speeds. And for constant speed, with variable outlet, the ratio increases with increase of outlet.)

2nd. The volume of air delivered per 100 feet of peripheral motion and per foot width of blade. This reduces fans of different dimensions and speeds to a common basis for comparison.

PERFORMANCE OF DIFFERENT FANS.

	Ser Type at Pracchia	GUIBAL TYPE (Kent)				
		A (Double)	C	D	E (Double)	G
Diameter of Fan	16.08	20′ — 0″	20′ — 0″	25′ — 0″	17′ — 6″	25′ — 0″
Diameter of Eye	6.86	8′ & 10″	8′ —10″	11′ — 6″	8′ — 0″	12′ — 0″
Width of Vanes	2.95	6′ +6′ =12′	6′ — 0″	8′ — 0″	4′ +4′ =8″	8′ — 0″
Depth of Vanes	4.00	5′ — 7″	5′ — 7″	6′ — 9″		6′ — 6″
Airdelivered per rev. c. ft.	2966	3130	1005	1532	3016	2756
Cub. contents of Annulus generated by the Vanes	424	3040	1520	3096	1522	3012
Ratio of Air delivered to contents of Annulus	7.0	1.03	0.66	0.49	1.98	0.91
Air delivered per 100 ft. of Peripheral Motion	5870	4946	1602	2043	5494	3514
Air delivered per 100 ft. of Periph. motion and per 1 ft. width of Vein	1900	412	367	255	687	437

The comparison between these figures is quite interesting. It is an established principle that, other things being equal, the volume of air delivered per revolution is proportional to the width of the vanes; and for unequal diameters, but equal in other respects, the volume is proportional to the diameter. Note, therefore, that the "Ser" fan, 16 feet diameter and 3 feet width, yields a larger volume of air per revolution than Guibal fans 25 feet diameter and 8 feet width, and is but slightly exceeded by two Guibal fans working together, each 20 feet diameter and 6 feet width.

Note also the marked differences between the ratios of air delivered, to contents of the annulus, for the several fans; and also the differences in the volume of air delivered per unit of peripheral motion and width.

If the Pracchia experiments stood alone as representative of the "Ser" type, we might be justified in rejecting this comparison; but we have other experiments which go to show that the Pracchia fan was even below the general average of the "Ser" type.

M. H. Tresca in a series of experiments on a forge fan of the "Ser" type, 0.5 meter (say 20 inches) diameter, and running at speeds from 830 to 1346 revolutions per minute, found the ratio of air delivered to contents of annulus equal to 10.

M. Francois, Chief Engineer of the Mines of Anzin, made numerous experiments with a mine fan of the "Ser" type, 2 meters (6.6 feet) in diameter, running at a constant speed of 240 r. p. m., and with varying orifice. He found for the orifice at which the pressure was a maximum the volumetric ratio was 7.3, increasing with larger orifices up to 13.1.

The Italian Commission, referring to Kenarte on "Ventilation of Mines" in the "Revue Universelle des Mines," 1893, say: "In fact, for the better fans used in mines Kenarte has found the following values:

TYPE OF FAN	Diameter	Breadth of Blades	Volumetric Ratio
Guibal.....	18.0 to 39.4	6.4 to 9.8	0.11 to 0.54
Cassel.....	8.2 to 12.3	5.2 to 9.8	0.42 to 0.54
Rateau.....	6.6 to 9.2	0.85 to 0.92	5.3 to 11.3
Ser.....	4.6 to 8.2	0.79 to 1.48	6.9 to 26.3
Ser (Pracchia).....	16.1	2.95	7.0

I have failed to find a description of the "Cassel" fan.

A description of the "Rateau" fan, illustrated by a diagram, is found in Hughes' "Text Book of Coal Mining," from which Fig. 5 is reproduced. It has from 24 to 30 vanes curved forward. From this sectional diagram the analogy between this fan and the "Ser" type, referred to on another page, is more apparent.

It has an unobstructed intake, the airway free from angles and abrupt bends, and a large number of vanes curved forward.

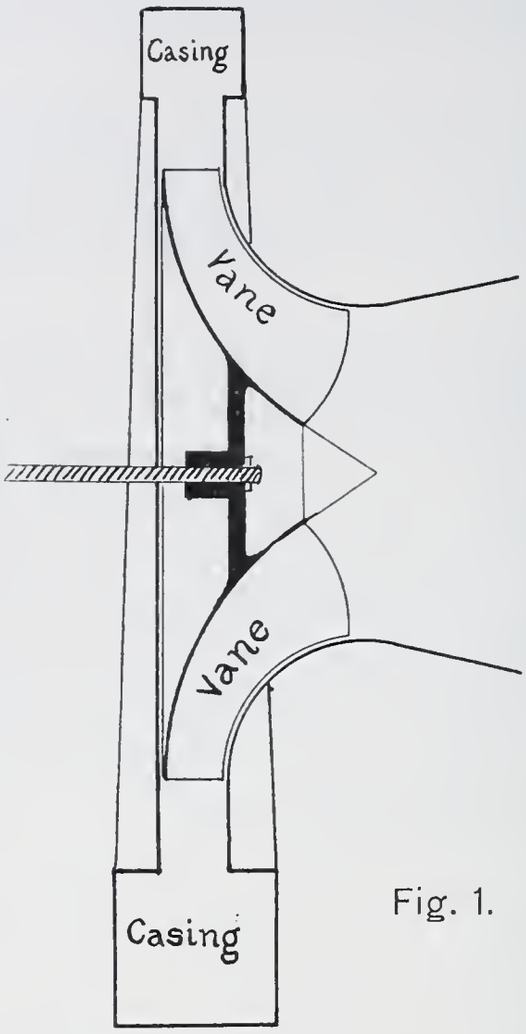


Fig. 1.

The high volumetric efficiency found by Kenarte for these fans, therefore, must be grouped with the tests of the "Ser" fans, as additional evidence emphasizing the importance of these features in the development of a perfect fan.

We have, therefore, in the foregoing data, cumulative evidence that the "Ser" type of fans are strikingly superior to other types in volumetric efficiency. Let us see if we can trace this to its cause or causes.

Considering first the number and form of blades and recalling the quotation from the "Coal and Metal Miner's Pocket Book," which says that an increased number of blades prevents backlash or re-entry of air into the fan, Ser's discussion of this feature is interesting.

It is illustrated by Fig. 2.

As the fan revolves the air passing up between the vanes is held in close contact with the forward surface of the vane; while the preceding vane by reason of its motion tends to create a vacuum behind it. The air escaping at the periphery

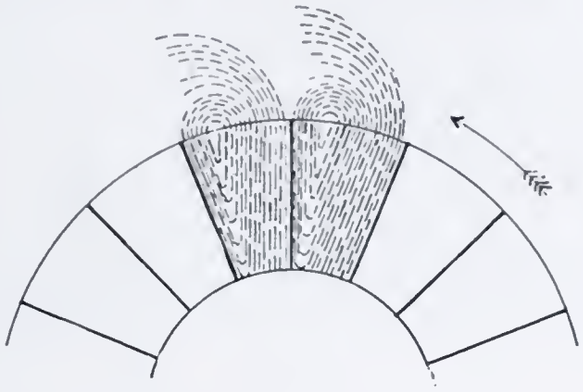


Fig. 2.

is thus drawn back in a constant eddy between the blades, about as indicated by the dotted lines in the figure.

This difficulty seems to have been early recognized by the French engineers, for Ser recounts several forms of fans designed to meet this condition.

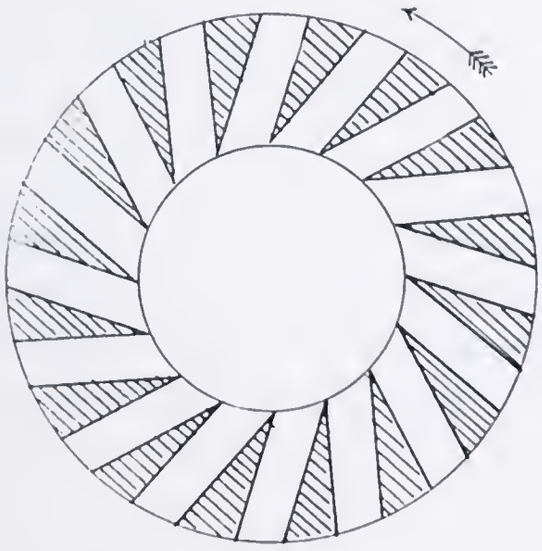


Fig 3.

M. Bourdon made the number of vanes large, placed radially and of trapezoidal form, the width reducing from the inner to the outer edge in such ratio that the sectional area of the passage between vanes shall remain constant.

In the "Lambert" fan re-entry of air is prevented by encasing the fan wheel in a cylindric shell, or drum, with a rectangular opening in front of each vane, equal in area to the opening between vanes at the inner circle.

Another device resorted to is shown in Fig. 2, in which the air passages were made absolutely constant in section by closing up the triangular space, behind each vane, in which the eddies and re-entrant filaments occur.

With a large number of vanes curved as in Fig. 4, the width between vanes will be nearly equal at all points, and there are no large spaces behind the vanes to be occupied by

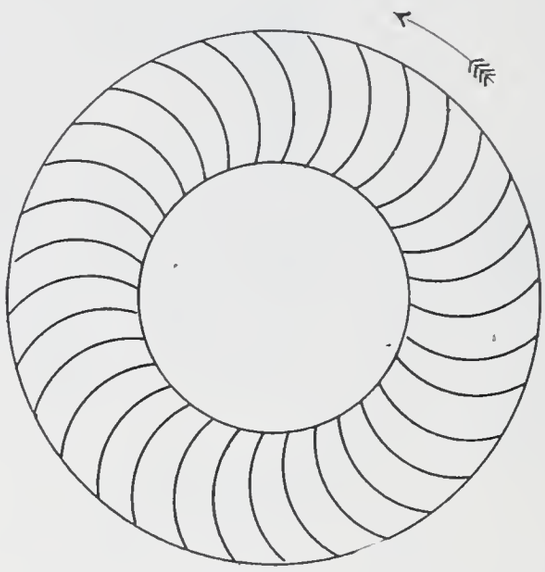


Fig. 4.

eddies. The constant section of the passage can be made absolute by reducing the width of the vanes, as in the Bourdon fan, except that in this case the side of the vane will have a curved profile, of which the ordinates are inversely proportional to the normal distances between vanes at corresponding points.

The reasoning of our French brethren on this subject is logical, and their conclusions would be entitled to acceptance on that ground alone; but that conclusion is emphasized by the following practical tests of three fans whose vanes differed in number and shape, but which were nearly alike in size and mode of construction.

1st. A "Decoster" fan, composed of a metal disc 2.2 feet

in diameter, with four plane rectangular vanes, riveted radially on each side. Speed 342 to 870 r. p. m.

2nd. A "Bourdon" fan, composed of a metal disc 2.5 feet in diameter, with twenty-four trapezoidal vanes riveted on each side in radial direction, except that the inner edge curved slightly forward. Speed 171 to 985 r. p. m.

3rd. A "Ser" fan, consisting of a metal disc 1.67 feet in diameter with 32 vanes on each side, curved so as to incline forward at both top and bottom, and with curved cones from the axle at the eye to the face of the disc at the inner edge of the vanes. Speed 830 to 1346 r. p. m.

The "Decoster" and "Bourdon" fans were tested by General Morin; the "Ser" fan was tested by Tresca, and is the same one previously referred to.

The volumetric ratios found were:

"Decoster" fan, 4 vanes, ratio 1.06.
"Bourdon" fan, 24 vanes, ratio 2.90.
"Ser" fan, 32 vanes, ratio 10.0.

These results fully confirm the reasoning which leads to the adoption of a large number of vanes; but the wide difference between the "Bourdon" and "Ser" fans is not in proportion to the number of vanes, and this brings us to the consideration of the effect of curvature in the vanes.

It was not the intention to introduce into this paper the general equations deduced by Ser. Indeed, it could not be done within reasonable limits. But to throw light on this subject of curved vanes, I will say that in Ser's equation for velocity of discharge from the vanes, and in some of his other equations, there occurs a factor in the form

$$\left(1 - \frac{r \text{ Cos } p}{R \text{ Cos } q}\right)$$

in which r. and R, are respectively the inner and outer radii, q, the angle which the vane makes with the tangent to the inner circle, and p. the angle at the outer circle, the angles being measured in both cases from the tangent produced backward as to the direction of motion.

Keeping in mind that at 90 degrees Cos equals 0, and for angles greater than 90 degrees the cosine takes the minus sign, we readily perceive that

$$\text{When } p=90^\circ \text{ then } 1-\frac{r \text{ Cos } p}{R \text{ Cos } q}=1$$

$$\text{“} \quad p>90^\circ \quad \text{“} \quad \text{do} \quad >1$$

$$\text{“} \quad p<90^\circ \quad \text{“} \quad \text{do} \quad <1$$

Hence a fan with the vanes curving forward at the top should always give greater efficiency than if the vanes are radial. This theoretical deduction serves to explain the difference between the "Bourdon" and "Ser" fans in the foregoing experiments, and conversely the experiments confirm the deduction.

When the blades curve backward ($r < 90^\circ$) the efficiency will be reduced. This accords with the statement in the "Coal and Iron Miner's Pocket Book" that "A certain curvature backward has been assumed by many to increase the efficiency of the fan. This has not been proved in practice. The effect seems to be simply to necessitate a higher speed to obtain the same results as with radial blades."

Turning back to the "Guibal" fans cited by Kent and by Kenarte, we find that these fans with 8 to 12 blades are low in efficiency, compared with the 4-bladed "Decoster," very low compared with the "Bourdon," and disgracefully low compared with the different "Ser" fans cited.

Referring again to the illustration of the Pracchia fan, please note its construction. It consists of a central frame which in passing from the rim toward the axle curves outward and terminates about in the plane of the "eye." This surface is covered with sheet metal, affording a smooth surface for the inflowing air to traverse. The vanes are attached to the sides of this frame.

Note also that the casing is finished with a curve at the "eye," avoiding sharp corners not only at the inner but at the outer face of the housing wall. Note the free passage for the air, without obstruction, hindrance or disturbance; its di-

rection being gradually changed from the horizontal at the "eye" to a radial direction at the vanes.

This is a characteristic feature of the "Ser" type. In the smaller fans a plane metal disc takes the place of the built frame of the larger fans, and the curved channel of intake is obtained by means of separate metal cones, slipped over the axle and attached to the disc; the housing or casing being finished with curves at the "eye," so that the inflowing air encounters no disturbing element to break up the continuity of the threads of the current.

On the other hand the "Guibal" fan, and some others, are constructed with two frames or wheels, to which the vanes are attached, and the inflowing air must pass through the planes of these spokes, or framework, to reach the interior of the fan.

Compare for an instant the facility of ingress afforded by the Pracchia fan with one in which the air must pass through a framework like that in Fig. 5 (reproduced from Mauchline's "Mine Foreman's Handbook,") while it is revolving at high speed.

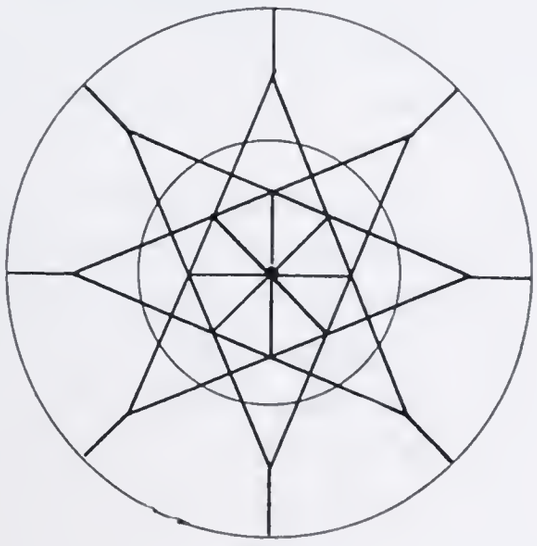


Fig. 5.

Imagine, if you can, that instead of invisible air, the fan were running in a visible fluid like water. How it would be churned to froth before reaching the blades! Is it any wonder that such a fan is low in volumetric efficiency?

Beard states that each fan gradually increases in efficiency with increase of speed up to a certain point, where it attains a maximum, and beyond which the efficiency rapidly decreases. This is readily understood when we consider the interference caused by the revolving spokes, just described. The result could not be otherwise. With increased speed a point is reached where the amount of air, which can force its way between the spokes, is just equal to the volume expelled by the vanes. This is the point of maximum effect. Further increase of speed increases the difficulty of entrance, and at the same time increases the expelling power of the vanes, and the discrepancy between the capacity of the intake and of the vanes increases rapidly with increase of speed.

Beard gives an equation for computing the speed of maximum efficiency, one factor in which he calls the "fan constant." It is a sort of "personal equation," to be determined for each individual fan before leaving the shop.

Ser's theory and formulae do not recognize a similar limit of speed, nor do the experimental data indicate that, with fans of this type, such a maximum point exists, at least within the range of speeds attainable with the plants used in the experiments. Beard's "fan constant" would therefore appear to be really a co-efficient of interference with ingress of air.

Failure on the part of fan builders to appreciate the importance of a free intake is further shown by the frequent practice of placing the supports of the journals close up to the sides of the casing, thus partially closing a considerable proportion of the area of the "eye," and necessarily creating whirls and eddies in the inflowing current, with corresponding detriment to the efficiency.

This, however, is of minor importance compared with the larger interference of the revolving spokes, and it is mentioned only as further evidence of the fact that builders have not realized that while they may control the mechanical power applied to move the vanes and drive air out, the inflowing air is moved only by the difference in the atmospheric pressures outside and inside the casing. The dif-

ference of pressure is necessarily small, and to give it the highest efficiency the movement of the air in its approach to the vanes should be as free as possible from disturbing influences and interferences.

In view of all the foregoing considerations we cannot escape the conclusion that the low volumetric efficiency of the "Guibal" fans is largely influenced by the obstructed intake, and the superior efficiency of the "Ser" type is due to

(a) Absence of interference at the intake.

(b) Large number of vanes, and avoidance of eddies.

(c) Curved form of vane discharging the air more nearly in a tangenital direction.

One other feature that I might add to that list is the form of the spiral casing. Many of the fans in use, and especially those on which experiments have been made and of which the results are accessible in the "Transactions of the Societies" and other technical papers, differ very widely in the form of the spiral casing. Some of them have a tight cylinder, close fitting for three-fourth of the circumference, and then expand only in the last quarter. Others fit closely for half the circumference, others for a quarter. Some of them expand throughout the full circle, but at such an insignificant rate that it does not afford free outlet for the air. I have in mind one in the table of experiments published by Norris in the "Transactions of the American Institute of Mining Engineers for 1891." There is one of the fans embraced in his list of experimental work in which the casing starts at the throat and expands to 9 inches at the first quarter, 18 inches at the second quarter, 27 inches at the third quarter, and 36 inches at the base of the chimney. But you can see that that affords no adequate outlet for the air which the blades are trying to drive out. These differences have given rise to apparent confusion, and prevent the deduction of valuable results from the experiments. In the Ser fan at Pracchia, it happens in that particular case that the enlargement of the spiral at the fourth quarter is equal to the radius of the wheel. I have not in my researches found any Guibal fan that approaches that. It is

not sufficient to provide the air with an unobstructed inlet, but you must not choke it back at the outlet with too tight a casing.

DISCUSSION.

Mr. Wm. Clifford, Mem. Eng. So. W. Pa.—(By letter)—In order to get a grasp of the value of fan experiments we should have all the data; and in making comparisons we should know the conditions under which the fans work.

Three elements which go to make a description of a fan test complete are:

(1) *Mechanical efficiency,* or the percentage of power applied to drive that is given back in the shape of work done, in volume or resistance on the mine or space ventilated.

(2) *The volumetric efficiency,* or the relation the volume of air thrown out per revolution bears to the cubical contents of the fan. The standard commonly adopted has been the total contents of the fan: the author of the paper, following Mr. Van Norris, adopted the contents of the annulus or displacement of the blade during one revolution.

(3) *The manometric efficiency,* or the proportion of the theoretical depression, $\frac{U^2}{2G}$ .00125x12=water gauge in inches, which is actually produced in operation of the fan under test, (and here it may be remarked that a fan can be built to give a very high manometric efficiency and very poor volumetric and mechanical efficiency, and vice versa). The fan that gives the highest mechanical, volumetric and manometrical efficiency during the same test is unquestionably the best, though low manometric efficiency is often an evidence that a fan is doing good work. When the depression due to tips speed of fan is in excess of the resistance of the mine it is utilized to produce volume, or, in other words, to increase the volumetric efficiency.

On the other hand the volumetric efficiency in a fan may be low, yet, it is working economically, but the depression due to tips speed is lower than the resistance of the mine to the

volume displaced, and only the volume the mine will pass can be thrown off by the fan.

Mr. Johnson in his paper says: "The fans are compared on two separate bases: 1st. The ratio of the volume of air delivered to that of the solid of revolution generated by the blades; that is to say, the number of times the fan empties itself in each revolution. (Experiments show that for the same fan, with constant area of outlet, this ratio remains constant at all speeds. And for constant speed, with variable outlet, the ratio increases with increase of outlet.)

2nd. The volume of air delivered per 100 feet of peripheral motion and per foot width of blade. This reduces fans of different dimensions and speeds to a common basis for comparison."

As to base of comparison No. 1 it may be said:

The percentage of body output certainly does not remain the same at all speeds with a constant area of outlet, because the increase of speed increases what Mons. Daniel Murgue terms the orifice of passage in a fan and the resistance at the inlet and outlet, and if the fan is doing actual work, ventilating the mine for instance, resistance increases as the square of the speed. In a properly designed fan, water gauge and volume are interchangeable quantities. The former increases (at the expense of the latter) with increase of resistance, while with diminished resistance the air increases and the gauge falls.

My experience of fans would lead me to take exception to the second base of comparison. A fan of smaller diameter but equal cubical contents, traveling at the same tip speed will give greater percentage of body output than a larger fan. This is especially true at high speeds.

No comparisons of the performance of fans are of value where resistance to the passage of air is not taken into account. Water gauge is not a function of the fan but of the mine. If a mine or tunnel requires an inch of water to pass 100,000 cubic feet of air per minute, the inch of water gauge must be produced before the 100,000 cubic feet will pass, whatever fan is used. Guibal by means of his shutter cut down the delivery

orifice of his fan until the water gauge and volume met in what he called the "temperament" of the mine. The restricted orifice produced the gauge and speeding up of fan put the volume through the smaller opening.

Taking the figures in table for "Ser" fan, page 394, they want the essential information as to resistances. Tests of fans working on free air are not "informing." Here we have a fan 16.08 feet in diameter with two inlets, each 7.86 feet diameter delivering 2966 feet per revolution. Assuming it makes one revolution per second, then 96 feet approximate area of two openings divided into 2966 feet volume equals 31 feet lineal velocity of air entering fan.

Lind and others found that to set up a current of 46 feet per second in the open 1 inch water gauge was necessary. On this basis the pressure of air entering a fan at 31 feet per second would be 0.45 inches without taking friction into account. If instead of one revolution the fan be speeded up to five revolutions per second, or 300 r. p. m., the speed of entry becomes 155 feet per second and the water gauge a prohibitory quantity.

Assuming this Pracchia fan to run 300 revolutions per minute 2996x300 equals 298,800 cubic feet per minute. This is a peculiar showing for a fan known for the last 25 years in France, where the coal mines are the poorest ventilated in Europe.

Ser fans have been tried in Germany and cannot hold their own against other fans where high resistance has to be overcome, notwithstanding that some of them had chimneys 60 feet high .

Mons. Kenarte is also a designer of fans of the Ser type, characterized by very high chimneys.

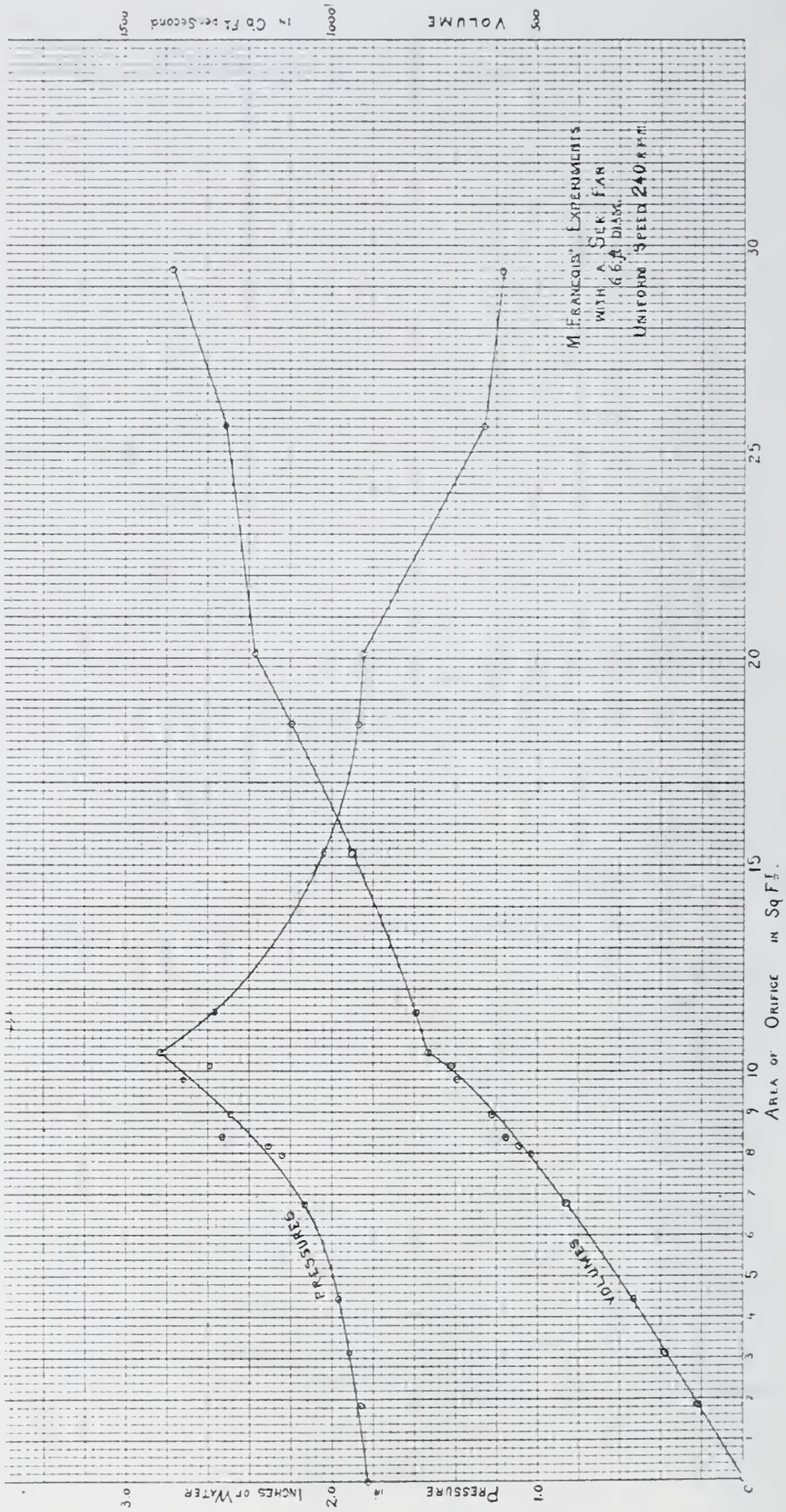
Fans with a great number of curved blades have been used before and since the publication of Ser theories.

The latest is Davidson's Sirocco, with its short blades, 64 in number, having a depth of about 1-15 the diameter of fan. All this type of fans have one weak spot—mechanical efficiency. The best positive fans of today can give them 30 per cent. on mechanical efficiency and beat them.

Fans 16 feet diameter, 5 feet 8 inches wide, giving 378,000 cubic feet of air per minute at 15 inches water gauge and 275 r. p. m., and a volumetric efficiency of 121 per cent. on total contents of fan, 80 per cent. mechanical efficiency, 68 per cent. manometric efficiency, have no fear of the rivalry of fans of the type under discussion.

Mr. Thomas H. Johnson—In preparing this paper I had no intention of going into the question of manometric or mechanical efficiency. I merely wanted to call attention to the influence of that structural defect which, as it appeared to me, hindered the inflow of air into the fan. That appeared to me a vital point and the experiments that I quoted emphasize it as such. Now Mr. Clifford attempted to criticize my statement that the Ser fan gave the results stated there. I quoted those figures from a report issued by the Italian government. In that report they gave the record of the work of the fan at different speeds, from 20 r. p. m. up to 70 r. p. m. They did not go beyond that because that was the limit of speed of the engine that was furnished them. But during or throughout that wide range of speed the ratio averaged 7. These are facts which cannot be argued away by any theoretical demonstrations.

Mr. Clifford also calls up another matter, that is, the relation of the resistance to the duty of the fan. I have here a diagram giving in detail the series of tests made by Chief Engineer Francois on the fan at the mine of Anzin, and it is very interesting. He ran the fan at a uniform speed of 240 r. p. m., or at least his results were reduced to the basis of that uniform speed. The vacuum developed, (he was working with an exhaust fan) are represented by the upper line in the diagram marked pressure. He started with the air chamber closed so that he was pulling against a tight chamber and with a water pressure of 1.83 inches. He gradually opened the orifice as represented at the different dots. The pressure increased following that curve until he had an orifice of 10.4 square feet. At that point the pressure became a maximum and beyond that it rapidly decreased with larger orifice, but with a pretty regular curve, up to about 20.3 square feet and beyond


M. FRANÇOIS' EXPERIMENTS
WITH A SER. FAN
6.6 ft DIAM.
UNIFORM SPEED 240 R.P.M.
VOLUME
IN CU FT PER SECOND
1500
1000
500
PRESSURE
INCHES OF WATER
3.0
2.0
1.0
PRESSURES
VOLUMES
AREA OF ORIFICE IN SQ FT.
0
1
2
3
4
5
6
7
8
9
10
15
20
25
30

that it gets irregular. I do not attempt to analyze these figures; but I thought it might be interesting to see how a fan behaves under these conditions.

Replying more specifically to Mr. Clifford, I would call attention to the example marked "G" in the table on p. 522 of Kents Pocket Book, which clearly confirms my statement

Experiments made by M. Francois, Chief Engineer of the Mines of Anzin, on a "Ser" fan 6.6 ft. diam.

(Results reduced to a uniform speed of 240 r. p. m.)

EQUIV. ORIFICE SQ. FT.	VOLUME OF AIR C. FT.—SEC.	VACUUM OBSERVED INS. WATER	RATIO	
			MANOMETRIC	VOLUMETRIC
0.83	0	1.83	0.60	0.
1.83	106 3	1.86	0.61	1.0
3.12	188.5	1.92	0.63	1.8
4.41	267.3	1.97	0.65	2.6
6.78	428.9	2.13	0.70	4.1
7.97	513.9	2.24	0.74	4.9
8.18	542.3	2.31	0.76	5.2
8.40	578.8	2.53	0.83	5.5
8.93	610.2	2.49	0.82	5.8
9.80	698.5	2.72	0.89	6.6
10.12	710.5	2.59	0.85	6.7
10.44	765.6	2.82	0.93	7.3
11.41	795.3	2.57	0.85	7.6
15.29	950.7	2.04	0.67	9.0
18.41	1097.2	1.87	0.61	10.4
20.13	1186.2	1.85	0.61	11,2
25.62	1253.5	1.26	0.42	11.9
29.39	1381.2	1.17	0.38	13.1

Area of EACH vane, 1.615 sq. ft.
Mean radius of vane, 2.592 ft.
Volume per second generated by the vanes at 240 r. p. m., 105.133 c. ft.
Dynamic efficiency at orifice 11.41–0.68.
" " " " 17.00–0.57.

that the volumetric ratio is constant for the same fan, at all speeds, when working against a constant resistance. As this book is in the hands of nearly every engineer it is not necessary to quote the figures here. Other experiments made abroad also point to the same conclusion.

I am unable to see anything "peculiar" in the result computed by him for the Pracchia fan—viz., 898,800 cu. ft. at 300 r. p. m. Such a result would not be abnormal for that fan at that speed, although I have not found any record of a Ser fan of that size having been run at so high a speed.

Compared with the fan described in Mr. Clifford's closing paragraph, the Pracchia fan would deliver his 378,800 cu. ft. per minute at 127 r. p. m., although of course, at less pressure, because of the slower speed. At equal speed the Pracchia fan would deliver a larger amount, equal to 815,600 cu. ft., and at substantially the same pressure as his fan; which, by the way, could not be 15 inches water gauge as stated. By the equation quoted by him the theoretic pressure would be 12 inches, and at 68 per cent. efficiency, the actual pressure would be only 8.2 inches.

I am surprised to learn that it is the common practice to compute the volumetric efficiency on the basis of the total cubic contents of the fan, instead of the contents of the annulus generated by the blades. It is not so treated by any writer to whose work I have had access; and I fail to see how such a practice can be justified by any line of mathematical or scientific reasoning. Does he mean that the practice is common throughout the country, or that it prevails only in the local territory?

I have seen no description of the "Sirocco" fan, but I take it the small depth of the blades implies a correspondingly large diameter of eye. According to the theory and formulae of Ser this would give a very large volume of air, as his formulae show that the volume increases with increased size of the eye; but such an excessive ratio of eye to diameter of the fan may lead to some other weakness, either in manometric or dynamic efficiency, as to the facts of which I have no information.

Mr. F. Z. Schellenberg, Mem. Eng. So. W. Pa.—In our vicinity the state of the art of fan construction has reached to massive structures in masonry and steel with powerful steam engines or electric motors to impel heavy Guibal or Capell fans.

It must be believed that we ought to learn more about other types hardly known to us; there are some smaller fans probably of improved new forms in good use here. Each machine is best when its size and speed suits the conditions of underground area it ventilates.

Mr. R. A. Cummings, Mem. Eng. So. W. Pa.—Are any of those fans constructed on the principle of ordinary electric fans?

Mr. Thomas H. Johnson—Yes, but they are low in efficiency. When applied to the handling of large volumes of air they are not economical.

Mr. Harry J. Lewis, Mem. Eng. So. W. Pa.—It may be well to make a brief statement of the conditions under which a mine fan works. It begins with short entries close to the fan. As the field is developed the air from the fan is forced into more and more entries and goes further away before it returns. My impression is that every fan has its certain conditions of water gauge and volume of air under which it will produce its best results. Now we only reach that point once in the life of the mine. We drive entries and develop skin friction and resistance of distance enough to come up to that point where the fan meets its proper resistance and water gauge, and with its proper volume of discharge for maximum efficiency. But we go on beyond that, driving more entries demanding higher gauge for the drag of the mine, and we ultimately go away from that condition of best efficiency.

Mr. F. Z. Schellenberg—The ventilation of a coal mine is a very serious matter where there is gas—and there always is gas. There is carbonic acid gas and there is fire damp.

Mr. E. Yardley, Mem. Eng. So. W. Pa.—What is fire damp?

Mr. F. Z. Schellenberg—It is carburetted hydrogen. It is natural gas to all intents and purposes, which is at its highest explosive point when it is mixed with ten volumes of air. Therefore the mixer in your grate should be just large enough to bring in ten volumes of air to one of gas.

Mr. Robert A. Cummings—It appears that all efforts in the direction of clarifying the atmosphere of tunnels have been confined to the mechanical means of ventilation, and Mr. Johnson has in a discussion on the subject of "Ventilation of Tunnels" presented at the International Engineering Congress, 1904, pointed out the significant fact that the increase of temperature within a tunnel is a measure of the impurity of the atmosphere.

Mr. Charles S. Churchill, Chief Engineer of the Norfolk & Western Ry., states in his paper on "Ventilation of Tunnels," in reference to the Elkhorn Tunnel, that the temperature of the atmosphere inside of the tunnel became about 30 degrees higher than the outside of the tunnel by the passage of a train; that is, with an outside temperature of 70 to 75 degrees, the temperature 1000 feet from the east portal was 103 degrees, and this became still higher as the outside temperature increased.

Obviously, if the clarifying or purifying of the atmosphere is all that is necessary for tunnel ventilation, why should we not take a hint and follow the methods pursued by nature.

All of us who have experienced Pittsburg "smog," which is a combination of smoke and fog commonly found in this locality, have noticed the clarifying of the atmosphere by a good rain. This suggests the thought that an artificial rain within the tunnel would reduce the temperature of the atmosphere and carry away most of the products of combustion. Almost all long railroad tunnels are located on "summits" and it has become a railroad axiom that "all summits are wet." Hence the tunnels provide the water supply for a pumping plant and piping system. This water might be under gravity pressure from tanks filled by hydraulic rams and issue from spray jets located at frequent intervals throughout the length of the tunnel. If water is scarce the spray could be operated automatically when needed by the passage of a train or other economical means adopted as the case suggests. It is thought that fine spray water falling from these jets would accomplish the object desired. Of course the changing of the atmosphere would depend upon barometric difference of pressure or the

adaptability of the particular tunnel to induce air currents by natural or mechanical means. But, is the changing of the atmosphere necessary if it is clarified or purified?

Mr. Thomas H. Johnson—About five or six years ago a gentleman in Baltimore wrote me on that subject, using water to condense and carry off the carbonic gases that are set free in a tunnel. He proposed to carry a large perforated pipe along under the roof of the tunnel and turn water in there, making a shower of spray washing down the air. I called on my friend Mr. Camp for some information as to the solvent power of water on carbonic acid gas and found from that data that to absorb the volume of gas that is thrown off from locomotives on a busy railroad demanded an amount of water that would supply a large town.

Mr. Robert A. Cummings—Mr. Johnson's answer seems to me to be theoretical. I know it is in practical application in this city in a large office building.

Mr. Thomas H. Johnson—The gentleman must realize that they are purifying ordinary atmosphere such as we are breathing on the street. The conditions in a tunnel where locomotives are throwing out carbonic acid gas and it is accumulating in such proportion as to become dangerous to life, is entirely different. The ordinary percentage of carbonic acid gas in air runs from 3-10 to 1-2 of 1 per cent.; after the passage of a locomotive through a tunnel it may run up as high as 10 or 12 per cent.

Mr. Samuel Diescher, Mem. Eng. So. W. Pa.—In 1863 there was a German engineer who experimented with submarine boats at the expense of the Russian government. They were larger than submarine boats are now, and in one of them thirteen men were under water twelve hours, and as a means of purifying the air and supplying it with oxygen he used a spray of water.

Mr. E. Yardley—I understand carbonic oxide is much more dangerous than carbonic acid.

Mr. Thomas H. Johnson—The two are always in conjunction. The average proportion from a locomotive is about 1-3

oxide to 2-3 acid, according to the conditions of the fire, the mode of firing and the attention given to it. It may run up as high as 1-2 or drop as low as 1-5.

Mr. J. H. Smith, Mem. Eng. So. W. Pa.—What is the solubility of carbon monoxide? My recollection is that it is something like one to one

Mr. Thomas H. Johnston—My recollection of the information I obtained on that point is that the solubility is largely affected by temperature. It is not the same at any two temperatures and varies within wide limits.

Dr. K. F. Stahl, Mem. Eng. So. W. Pa.—Carbonic oxide is much less solubile than carbonic acid

I understand they use water in the Simplon tunnel for cooling, not for purifying, because it is unbearably hot on account of the hot water. They introduce cold water from the outside to cool it.

Mr. Thomas H. Johnson—It may be well to say a word about ventilating railroad tunnels. I may say briefly that the principle as now developed, first by Mr. Saccardo in Italy and later by Mr. Churchill in this country, consists in forcing into a tunnnel, with a fan, a sufficient volume of air to dilute the gases to the point that men may live in it with comfort. It was found in the experiments at the Pracchia tunnel that when the combined carbon gases do not exceed 1 per cent. the men passing through the tunnel call the air good; when it reaches 2 per cent. they call it bad; and in the course of the experiments there was an unfortunate accident which enabled the Commission to say that 3 per cent was fatal.

Dr. K. F. Stahl—Do they work from one end of the tunnel or from both?

Mr. Thomas H. Johnson—From one end.

Mr. F. Z. Schellenberg—How is it in the long Alpine tunnels?

Mr. Thomas H. Johnson—The same. The St. Gothard tunnel is ventilated by fans of the Ser type, and the Appennine tunnel at Pracchia the same way; also one or two others.

Mr. F. Z. Schellenberg—Do they use a relay of fans in the long tunnels?

Mr. Thomas H. Johnson — No. You would be simply pumping bad air from one fan to another. And it would be a very awkward situation to try to set up a plant in the middle of the tunnel, especially if you used coal as a source of power.

Mr. R. A. Cummings—What is the direction of the air current as to the direction of travel?

Mr. Thomas H. Johnson—Mr. Churchill in his work recommends blowing in the direction of travel, that is behind the train. Mr. Saccardo blows the other way. I think the latter plan the better, as with the former you are blowing the gases right along with the train or else the speed of the train must be slowed up to let the air current outrun the train.

Mr. F. W. Winter, Mem. Eng. So. W. Pa.—I should think the friction in a tunnel ten miles long would be something enormous.

Mr. Thomas H. Johnson—So it is and that is a case of adjusting the fan to meet the requirements of the situation.

Mr. F. Z. Schellenberg—In a tunnel like the Alpine tunnel the current would be naturally upward to the high end; they have very little difference in elevation considering the length, but the tendency with the heated air within would be to go to the high end.

Mr. Thomas H. Johnson—That is not always the case. Tunnels under a mountain range may have an equable climate on one side and a cold, chilly air at the other, and the direction of the natural current would depend a good deal on conditions of that kind. In the Pracchia tunnel the grade ascends from the south to the north, yet the records show that the natural current flows from the north to the south more frequently than the other way.

Mr. Arnold Stucki, Mem. Eng. So. W. Pa.—When I went through the Elkhorn tunnel I found the gases very obnoxious, although the tunnel is not quite a mile long. Just the reverse I found to be the case, when I went through the St. Gothard

tunnel, which is about eight miles long. There you would not detect any difference in the air of the car whatever.

Coming back to Mr. Cumming's scheme, to clarify the air by water. I suppose the Simplon tunnel would offer advantages having a continuous heavy stream of water issuing from the interior.

Mr. G. M. Campbell, Mem. Eng. So. W. Pa.—About using water for cooling in one of the office buildings in town, they use it to eliminate dirt or soot, and it works very effectively on that point Of course the air is fresh and sweet to start with in comparison with the air in a tunnel. The water that is used goes in fairly alkaline and comes out just at the neutral point or sometimes acid.

They use fans for forcing the air into the building and also for sucking the air out of the building; and from experiments it has been found that when they stop the outlet fans the supply of air for the building falls off from 40 to 45 per cent.

There are a large number of sprays arranged so that the air passes through three separate sheets, practically three walls of very finely divided water. It has to be in an extremely finely divided state before it will take the dirt out. So in using water for absorption purposes in a tunnel, before it would be of any use at all it would have to be very finely divided. Ordinary water trickling down would not purify the air.

In regard to the cooling, part of it is due to evaporation of the water, which of course adds to the humidity, but in the summer time when they use cold water the humidity in the building is actually lower than it is outside, that is the actual weight of water, not necessarily the percentage. In the winter time the air generally is very dry and the addition of the moisture I think is advantageous.

THE DETERMINATION OF SULFUR IN IRON BY THE EVOLUTION METHOD.*

Mr. H. E. Walters, Mem. Eng. So. W. Pa.—There is a point I would like to bring up in regard to the determination of sulfur in iron by the evolution method. Before mentioning this point I would like to ask Mr. Dickson whether, when he read his paper before the American Foundrymen's Association, he believed that the sulfur was actually lost.

Mr. W. E. Dickson, Mem. Eng. So. W. Pa.—I didn't go deeply enough into the question to know what did happen, but my idea was that probably some oxidation took place on account of the very large exposed surface in the drillings. I didn't find that the sulfur standards that were made from steel, lost anywhere near as much as those made from pig iron or cast iron of any kind.

Mr. H. E. Walters—I always thought that by annealing you could get all the sulfur, as was proved afterwards. That would indicate that it was not oxidation.

We had a standard that was in a fine state and it didn't change at all. But a standard which we made a couple of years ago has recently changed, and the point I wish to notice concerns this change. When the standard was made determinations were made by the following methods:

1. The aqua regia method.
2. Evolution of the sulfur as hydrogen sulfid, absorption in an ammoniacal solution of cadmium chlorid and titration with a standard solution of iodin.
3. Evolution of the sulfur as hydrogen sulfid, absorption in saturated bromin water acidified with hydrochloric acid, and weighing finally as barium sulfate.

By all these methods the sulfur in the standard was found to be 0.059 per cent.

Recently it was found that determinations by the second

*Meeting of the Chemical Section Sept. 21, 1905.

method gave a value of 0.050 per cent., but that by annealing the sample taken the result obtained was again 0.059 per cent. If the third method was used the result obtained was 0.050 per cent., both before and after annealing the sample.

To investigate this discrepancy the following methods were tried:

The sulfur evolved from an unannealed sample was absorbed in cadmium chlorid solution and the cadmium sulfid obtained was filtered off. The sulfur in this was determined—

1. By solution of the precipitate in a mixture of potassium chlorate and hydrochloric acid, and precipitation and weighing as barium sulfate.

2. By solution in a mixture of saturated bromin water and hydrochloric acid, with precipitation and weighing as barium sulfate.

The result by both these methods was 0.059 per cent sulfur.

An annealed sample examined by the same methods also gave 0.059 per cent. sulfur.

The curious thing about the standard is that all the sulfur is evolved whether the sample is annealed or unannealed, and that annealing enables us to get correct results with the iodin titration method, but not with the method using bromin as an absorbent. The aqua regia method gives 0.059 per cent. sulfur in both cases.

The following results were obtained on American Foundrymen's Association standards:

Standard	Official value		Values found			
			Iodin method		Brown method	
	Volumetric method	Gravimetric method	Unannealed	Annealed	Unannealed	Annealed
B	0.038	0.056	0.030	0.057	0.029	0.048
C	0.059	0.076	0.047	0.074	0.046	0.067
D	0.024	0.031	0.019	0.030	0.018	0.029

Mr. W. E. Dickson—I would like to ask whether you ever found any steel standards which change in this way?

Mr. H. E. Walters—I have never known a steel standard to change. An article published some time ago spoke of changes of 0.003 per cent., or something like that, but there is no use in mentioning that because duplicate determinations will not check closer than that.

Mr. J. R. Mardick—(Non-member)—In annealing don't you think there is a rearrangement of the molecules?

Mr. H. E. Walters—That is the theory. It seems that annealing breaks up the organic sulfur compounds, although no very high temperature is used for annealing. The way I originally annealed was in a glass tube over a Bunsen burner in a stream of natural gas. There appears to be a rearrangement there so that the sulfur is all evolved. It is apparently the normal cadmium sulfid which is formed, because if it were an organic sulfid it probably would not react with the iodin.

A CO-OPERATIVE PLAN FOR SYSTEMATIC RESEARCH WORK.*

JOHN R. MARDICK,

Non-Member.

In the last five years there has been great discussion in this country as to the kind of men our technical schools should turn out to take positions in the technical field. The chemists and other technical men graduated from our universities can never fill the places as superintendents and operators wish. There are many reasons for this deficiency, and it is not for me to say what they are, but one is that we cannot expect a man to be well trained when the trainer does not come up to the outside requirements. That is not in any way said to disparage the men who are doing noble work in our institutions of learning, but they are too isolated, too much outside the practical field. They do not know the technical requirements and consequently they turn out men entirely theoretical or trained on too narrow foundations.

The program of the thirty-second general meeting of the American Chemical Society announced that "the chemical plants both in Buffalo and Niagara Falls refuse admittance." This policy of exclusion on the part of the manufacturers is not new; nor is it confined to chemical industries. Most of the industries based on experimental scientific principles, chemical, electrical, mechanical, especially those in their first stages of development, refuse all visitors. In fact, only soap works, breweries and natural food plants open their doors to the public. There are good reasons for this exclusive policy and

*Read before the Chemical Section, Sept. 21, 1905.

the manufacturers cannot be blamed for it. Some industries are either in a nascent state, requiring special care in their development, or are hard-pressed by domestic or foreign competition, so they feel obliged to zealously guard their processes, lest "trade secrets" leak out and undermine their success. It is also true that many visitors in disguise have abused non-prohibitive privileges by taking drawings of machinery and other appliances to the detriment of the manufacturers.

This general policy of exclusion has had a direct detrimental effect on those representative institutions, educational, scientific and commercial, which are called upon to advance new theories and ideas in the field of sciences and industries; that is, these institutions remain isolated from the practical field; and most of the theoretical work carried on by the professors, who are also out of touch with practical technical problems, or under their direction, has little if any practical bearing on every-day problems.

It is evident that, under these circumstances, the research work can be carried on only at random, just as it comes to the notice of the investigator, without any systematic planning as to its application to industrial developments.

This condition of things is not in harmony with the prevalent notion that the American people are highly practical. It is an indisputable fact that we have yet to learn the German method of research; viz., to deduce theoretical questions from practical problems. If our investigators were better acquainted with outside technical difficulties, their laborious and painstaking work in the realm of theoretical sciences might throw valuable light on many industrial questions, some of which need immediate solution. While we would not reflect on the character of research work carried on in our colleges and universities, or belittle in any measure its scientific value, one cannot fail to notice that it is mostly theoretical, with little direct application to industries. Theoretical work no doubt has its value in the general advancement of pure science; yet the same end can in many cases be better accomplished by investigating a practical problem from a theoretical standpoint, and thus "killing two birds with one stone." There are today innum-

erable difficulties and problems in many branches of the various industries which will not only furnish questions for discussion and theoretical speculation, but whose solution will be of great service to these industries and also to the community.

To be concrete, let us take one illustration from the chemical field. At present our knowledge of the molecular structure and state of hydrolysis of aluminum and chromium salts in solution is very limited, so much so that it is almost impossible to determine with accuracy the free acid in either alum or chrome-alum. As soon as the aluminum or chromium salt goes into solution it forms a different compound from the same salt in a dry state; it is hydrolysed in such a manner that a basic salt is formed and sulfuric acid is liberated, as appears from the following equations:

$$Cr_2 (SO_4)_3 + 2 (H.OH) = Cr_2 (OH)_2 (SO_4)_2 + H_2 SO_4$$
$$Cr_2 (SO_4)_3 + 4 (H.OH) = Cr_2 (OH)_4 \ SO_4 + 2H_2 SO_4$$

Of course this reaction is shown only in a simple way, but other complex inter-molecular compounds are formed. The hydrolysis in this case is a function of three variables; concentration, temperature and time. The free sulfuric acid has no apparent solvent action on the basic salt, and in titrating with an alkali the basic salt precipitates, while the solution still remains acid. This free acid determination is of immense importance in the manufacture of chrome-leather, which as is well known in the last ten years has revolutionized the upper leather industry. The free acid first retards (in the one bath chrome process) tanning, by decreasing the affinity of chrome for hide matter; secondly, it attacks the hide fibre itself, producing thereby a cracky leather, of which the community so often complains. If it were possible to know the molecular structure of such compounds as chrome-alum in water solution and the extent of hydrolysis at known concentration and temperature, it would then be possible to calculate acidity and thus control this important process in leather making. What is true of aluminum and chromium salts is true also of the iron, zinc and other salts of this group.

It is very natural to think and expect that chemists in

their research work will take first these common substances and subject them to investigation, but human nature is generally interested in obscure and dark or fanciful things, and they usually prefer to dig up radium, glucinum, columbium, krypton, helium, scandium and other rare elements, while the most common salts, like iron and aluminum, are neglected. Thus, we have a great fascination in the search for the North Pole or in a air-ship. Every year millions are wasted on such fool-hardy experiments, while within our bodies infinitesimal microbes eat the life out of us. Well, these are not so fascinating as to awaken general interest in their investigation.

One is reminded of an ancient Greek scientist, who in his eagerness to search the heavens did not take heed to his steps and fell into a ditch. A woman, seeing this accident, advised the scientist to investigate his surroundings before gazing at the heavens.

In the last ten years a vast amount of research work has been done in hydrolysis and conductivity measurements for the development of chemical equilibrium and theory of dissociation. Yet the same end might have been reached by investigating chemical substances used in industries and thus have served both the chemistry and the industry. A casual glance over the topics published in the various journals and those submitted to the last general meeting of the American Chemical Society will illustrate very well our statement. For example:

"The Study of Mercury Sulpho-Cyanate Complexes."

"The Hydrolysis of Ammonium Acetate and Ionization of Ammonium Hydroxide and Water at High Temperatures."

"Some Properties of Metal Ammoniums."

"The Electrical Conductivity of Liquid Ammonia Solutions."

"The Solubility of Lead Sulphate in Ammonium Acetate Solution."

"The Synthesis of 5-Nitro—4-ketodihydroquinazolines from 6-Nitroacetanthranil and Primary Amines."

"On Isomeric O—and N-Ethers Derived from 2-Alkyl—4-oxynitroquinazolines and 2-Alkyl—4-keto—5-nitrodihydroquinazolines."

"Some Acyl Derivatives of Homoanthranilic Nitrile and the 7-Methyl—4-ketodihydroquinazolines Prepared Therefrom."

"The Condensation of Succinylosuccinic Acid Diethyl Ester with Guanidine: A Derivative of 1, 3, 6, 8—Naphtotetrazine, a New Heterocycle."

Recently the head of a technical school, in reply to the statement that Pennsylvania has 200 tanneries managed without particular reference to scientific principles, informed the writer that there are 700 bakeries within 20 miles of Pittsburg run according to the "thumb rule." How many of the chemists know anything about the science of bread making or have given any study to its development? While it is easy to critisize the modern woman for her ignorance of the art of bread-making, it is only candid to acknowledge that her scientific brothers do not know any better the chemistry of bread-making. In the same way the manufacturers of pottery, glass and enameled ware, while evidently in a flourishing state (especially around Pittsburg) are based on actual experience rather than on scientific knowledge. Most of the physical and chemical changes occuring during fusion (or firing) are but partially understood, so much so that when a practical man dies he carries with him all his experience and leaves nothing to posterity. We have often heard of old Greek fire and Egyptian embalming. They were based on practical experience and when the practical men died the industry was buried with them.

We have not yet touched the other fields of engineering, civil, mining, mechanical, electrical, in which momentous difficulties and problems daily confront our sanitary and constructing engineers. But it is easy to see that whatever holds true in chemical engineering also holds good for all kinds of engineering and human enterprise.

A personal canvass was made among many technical men, graduates from leading universities, as to the truth of our statements. All agreed that not only is a rearrangement necessary in the curricula of colleges with reference to technical education, but also that a wide personal acquaintance on the

part of instructors and students with outside practical problems will greatly enhance the value of technical education.

These facts indicate; first, that there are many scientific technical problems in industries which are neglected and which need immediate attention; secondly, that much energy is wasted on Utopian questions without apparent or immediate results. While all these investigations may eventually prove useful, we believe that a certain co-operation between investigators and practical men would be highly beneficial both to science and to industry. Even though manufacturers refuse admittance to their plants, they will be glad to discuss or even to submit problems for investigation. There are today hundreds of graduates from the engineering departments of colleges like Harvard, Cornell, Columbia, Yale and Mass. Institute of Technology, engaged in almost all branches of industries. Their actual knowledge of the workings of scientific principles in different processes would be a great help to the investigators who are in position, on account of the many facilities at their command in the equipment of the schools, to carry on research work more successfully than could be done by a technical man, hard-pressed under the exacting demands of routine work. This combination of practical knowledge and leisure for research will, we believe, yield the largest results obtainable for the benefit of all.

As an attempt at co-operation we suggest the following tentative plan:

Plan: Let every department of a college, university or other institution engaged in research work, invite its alumni once each year for conference: viz., the electrical, chemical, mechanical, mining and civil engineering departments each its respective graduates; let each department, in a separate section, open discussion in its own line, its alumni from their practical experience suggesting problems that most need investigation. Then during the course of the coming year the heads of these various departments, thus supplied with up-to-date practical questions, will be able to interest their assistants and graduating students in research and thesis work. More-

over, the alumni will be in a position to supply material for investigation.

There is no question that this or a similar co-operative plan, without limiting the investigators as to their choice of topics for research work, offers additional advantages.

First: The research work will be thus placed on a practical co-operative and systematic basis.

Second: There will be on exchange of ideas, the mingling of practical and theoretical minds, beneficial to all concerned, professors, students and alumni.

Third: The industries and the public in general will receive greater benefit from the work of the colleges.

Fourth: The alumni will thus retain a closer relation to their respective institutions.

We must not forget that the communities which support the institutions have a right to expect something tangible in return, and if we fail to put our scientific and educational work in harmony with the needs of the public our universities will fall far short of serving their original purpose.

DISCUSSION.

Mr. H. E. Ashley—(Non-member)—I once took a course in organic chemistry—not that I ever expected to use it, but only that when it was discussed I would have some grasp of the conversation—and while I do not recollect just what all those chemical compounds are, yet I have a dim idea that they are some relatives of dye-stuffs. Now the dye-stuff industry is a pretty important industry, although not around Pittsburg. Another subject mentioned, that of phosphates in the presence of ammonium sulfid, I recognize as having something to do with some investigations being made on the potability of drinking waters. These papers, if you are not acquainted with what the author is trying to get at, do appear very vague and far off. But it may be that the man who is actually working on that paper is out of touch with the people who are or ought to be benefited by it.

Mr. Mardick spoke of various industries of this neighborhood which need the touch of science, as the pottery and glass industries. Last winter at a meeting of this Society I met a man who told me he was a glass chemist. I am myself employed in a pottery where there is one other of the same profession, and I know a number of neighboring potters all over the country are employing technical men. The potter is a very conservative man and thinks a long time and gets pretty hard knocks before he makes up his mind, but I think that in ten years from today potting will be a recognized branch of chemical technology rather than an empirical science.

The necessity of co-operation between works and schools is a real one. I remember when I was taking up my thesis, metallography was just coming to the front and I wished to do something in it. I could not find any one that was very much interested in it except one of my instructors and he was having an argument with an organic chemist as to selenium and tellurium, so I went ahead and made some alloys of these. It never did me any good directly, but indirectly in working up those things I came across ideas that have been as invigorating and inspiring in my subsequent work as anything I could desire. I don't think it at all wasted.

If we could get that correspondence going back and forth it would be a good thing. The trouble has been inertia on both sides.

Mr. J. R. Mardick—In making these remarks I did not mean that there are not chemists engaged in potting or that there are not men engaged in making dye-stuffs and things like that. But so far as I can learn the men who wrote these papers on ammoniums and organic substances did not investigate these subjects with any knowledge of industrial developments. I would suggest that if one is going to investigate any property of chemical compounds, say ammonium compounds, he should first study the manufacture of the substance and theorize afterwards. My observation and the experience of technical men whom I have consulted on the subject is that our professors are far away—are isolated from practical fields. Manufacturers refuse admittance to their works. Even

some professors might object to having practical men come in and give them suggestions. There should be co-operation between these two forces to get any real benefit.

Mr. H. W. Craver, Mem. Eng. So. W. Pa.—I no not feel myself competent to judge of the value of such papers as those mentioned by Mr. Mardick. Their results may be of immediate practical value, or their immediate interest may be only theoretical, which only means that our knowledge is insufficient for practical purposes. But outside of the question of the value of such work, in my own work with the literature of technical chemistry, I continually feel the scarceness in many lines of literature which has any real value. In the case of many technical and industrial problems in chemistry, the descriptions of methods are still largely empirical. It seems to me that if some of the problems of immediate practical importance could be investigated in some such way as Mr. Mardick offers to us this evening, it would be a great help in a great many technical lines.

Mr. J. H. James (non-member)—I have been in teaching and technical work both. I think that if in America we could have a closer connection between technical schools, universities and colleges on the one hand and the works on the other, chemical technology in America would probably be further advanced than it is. While not educated in Germany myself, I believe it is a fact that there is a closer connection between the institutions of learning and the works over there. So we need it in this country. I heartily agree with Mr. Mardick, and I think that his is a very good plan.

Mr. J. E. Ober (non-member)—As far as my experience goes I think the problems that would go to the students would be of such character that it would be impossible to finish them in the time given. I do not believe that the manufacturers would be willing to give problems, the solution of which would benefit them, to the public. I know that one company in which I am interested investigates as secretly as possible all such problems. And of these problems very few can be finished in a short space of time. Of course there may be some

problem that could be finished in the time given to the student. But from my experience I think that as a rule the necessary time cannot be given.

Mr. H. W. Craver—Mr. Ober is interested in one of the comparatively few companies which appreciate research work sufficiently to employ men in it. I think there are, however, many problems that could be discussed for outside research in other institutions. As far as the question of time is concerned, I have known of researches running through four or five college years, one set of students carrying it a certain distance ,then students of the next year taking it up and carrying it further, and so on to final completion.

Mr. H. E. Ashley—I have noticed that quite a number of the students in technical schools are boys whose parents are connected with works that are related to the studies they are taking up, and in these cases I think the connection between the works and the colleges is pretty close, because the boy is carrying all the time in his mind the technical problems with which he is familiar. I know of a number of boys who completed three years of their course last June and were advised by their professor to go out and work a year in their chosen lines and then come back and finish their fourth year. I think perhaps that is in the line of what our speaker of the evening is trying to effect.

Mr J. R. Mardick—Is this society willing to take up this educational question—to get back to our subject—and push it so as to accomplish some results? If not, I am not discouraged. I will try to interest other scientific societies. I am simply making a proposition now, and I would like to know, for I intend to push it myself.

Chairman—Just what do you wish us to do and in what way do you wish us to act?

Mr. J. R. Mardick—For instance, we have here a plan. We endorse it perhaps with certain modifications, and we commend it to the consideration of educators, manufacturers and business men.

Mr. C. H. Rich, Mem. Eng. So. W. Pa.—Mr. Mardick

voices certain views in his paper which might be matters of individual opinion; certain specific things he has recommended. I, for one, do not think the society could very well take positive action on it at present on that account. We might express our sentiments as being in a general way favorable to the plan he has proposed. I do not believe we should go much farther than that.

Chairman—Will Mr. Rich make a motion covering those points?

Mr. C. H. Rich—I move that the meeting express its appreciation of the paper read by Mr. Mardick and its belief that the plan proposed by him is one worthy of thoughtful consideration.

The motion being duly seconded, was carried.

Mr. H. E. Ashley (communicated after adjournment)—In connection with this discussion I wish to add that the efficient college technical instructors I have known have always been engaged in outside consulting practice. It is, I believe, generally understood that these teachers are to be given opportunity to supplement their salaries by outside work. My own school is practically the training school for the higher grade of employes for a number of important industrial companies, with the heads of the departments engaged as their regular expert advisers and the school management to a considerable extent adapted to their needs.

The following extracts from an article in the Staffordshire (England) Sentinel of September 9, 1905, may prove of interest.

"A meeting of considerable importance to pottery students attending the County Council classes was held at the Town Hall, Tunstall, on Wednesday evening, when prizes were distributed and a new scheme of encouragement to study was enumerated by Mr. F. Rawdon Smith, Chairman of the Joint Committee of Manufacturers' Associations. With the object of encouraging people to take full advantage of their opportunities in order to foster the local industries, the Committee of the allied manufacturers in this district had gone to a con-

siderable amount of trouble and given much thought in the preparation of a scheme whereby they might assist the County Council. They wished to encourage research in subjects connected with potting, and he hoped the example the potters had set would be followed by those associated with other industries in the district. Everything was not yet settled with regard to iron as well as other important trades, and it was certain that everything was not settled in the potting trade. The committee had decided to offer prizes to post graduates—students who had passed the final examination of the City and Guilds Institute. Potters had a vast number of questions which required solution, but many of them were afraid to confess their ignorance. When he first began to "pot" he thought he knew every mortal thing about it after a very short time, but now, after thirty-four years' experience, he had come to the conclusion that he knew very little indeed about it. The manufacturers present would probably admit that the more they knew about potting the less they found they could say they knew all about it. The Manufacturers' Committee had selected three problems to occupy the attention of students next year. They had sufficient problems for the following year also, and they were inviting all potters to send to Dr. Mellor any question, whether from the profit point of view or the public point of view, which formed a difficulty to them. Such questions would be placed before the sub-committee without the names of the inquirer being divulged, and it might be that an inquirer might put a question the solution of which would mean thousands of pounds in this district. From the students the manufacturers would eventually take their scientific directors; they would be the men in years to come who would vastly assist—he could not say how vastly—in the promotion of the welfare of the industry. The Chairman then read the following suggestions for investigation which had been formulated by the committee:

Three prizes of £10 each, together with diplomas, are offered by the Joint Committee of Allied Manufacturers for the best investigation upon the following subjects:

(a) The best investigation on the causes and cures of the

scurf or scum which frequently occurs on the edges of plates, etc., on drying.

(b) The best investigation on the causes of a defect arising on glazed surfaces, especially earthenware, during the enamel kiln fire, which causes such defective piece to take a streak off silverware.

(c) The best investigation of methods for the economic production from local materials of durable saggers."

*MACHINE SHOP PRACTICE.

G. M. CAMPBELL,

Member Engineers' Society of Western Pennsylvania.

Good machine shop practice may be said to be the arriving at the desired result at the lowest cost. Whatever can be done to cheapen production is a step forward. Very much might be said about rules and procedure for maintaining discipline, for the systematizing of output, for the installation of the piece-work system or the many modifications thereto, and many other points; these, however, will be but briefly touched on. Attention will be directed chiefly to the equipment of the shops to indicate how very much can be done in the way of cheapening output.

The general management of a large machine shop is a subject in itself. The control over the shop should be very complete, and as much a one-man control as possible, not that one man should actually supervise the shop but that he should control every department through competent assistants, each assistant or foreman having trusted foreman or subforeman under him. The utmost care should be taken to have all the work performed systematically, so that the time lost in handling work is reduced to a minimum. Again, the utmost care should be taken to turn out good work, for in the end any concern doing poor work is doomed to failure; not only should the workmanship be good, but the parts turned out should all be to gauge within a pre-determined limit of error, the allowable error being determined by means of limit gauges.

The general scheme of handling the men, whether by day work, piece work, premium or other systems, is also a subject in itself. Each system has advantages and disadvantages. The men should be under careful supervision, but at the same time not watched as if they were trying to cheat the company.

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*Meeting Mechanical Section, October 2, 1905.

A speed foreman or a man whose duty it is to speed up the tools to the proper point is generally obnoxious to the men unless he has exceptional tact. The work can be done by a sub foreman without the special title. The good will of the men should, as far as possible, be obtained by making the surroundings comfortable and healthy and paying a good wage to keep good men.

An efficient tool room is a requisite of a good shop. In it the tools should be kept in some good system and should be kept always in the best of condition. The machines in this department should be high class, otherwise their imperfections will be reproduced in the tools. In the larger shops it is the duty of the tool room to not only see that certain tools are on hand for doing the work but to see what jigs or other fixtures could be made to cheapen production, and to consider in general the best way to handle any special job.

The general stores department is of immense importance, for on it depends very much the profit or loss that the company will incur. The only possible way to prevent shortage, to reduce stock to a minimum, to keep an exact inventory of material on hand, to make certain that all outgoing material is charged to the right account and to prevent delays in the manufacturing department by having ready to deliver the proper material at the required time, is to create a general store-keeping department for finished and unfinished material in charge of a good general storekeeper and under him a sufficiency of clerks.

General management, tool supply rooms, general stores department, accounting departments are classed as non-productive, though of course without efficient service in these departments no works can pay. But the works themselves, the machines and men doing the actual labor, are where the money comes from, and it is there that the greatest reduction in cost must be made. In general it will be found that as the productiveness of the shops increase the non-productive labor will also increase. The great cost in all shops is the labor. Anything to cut down the relative cost of labor is a step in the direction of greater profit for the manufacturer, not necessarily

to cut down the rate of wages, but rather the reverse, but to still further increase the output per man. The means for increasing the output may be taken up under these heads:

1st. Multiplying tools.

2nd. Multiplying machines.

3rd. Improving the quality of the cutting tool.

4th. Increasing the speed and ease of handling the machines.

MULTIPLYING TOOLS.

"One machine—one tool—one man," was the old rule since the operation of the first machine, and if some short-sighted trades' unions had their way, would still be in force. But such is no longer the case in live machine shops. Many single spindled drills are, for special work, replaced by multiple spindled drills, so that with one operation half a dozen or more holes are drilled, gaining very greatly in time and also in having the output absolutely interchangeable, a point of the very highest value. Single-headed planers are now the exception except in small sizes; planers cutting on both the forward and return stroke have been used but are not generally approved; plate edge planing machines cut both ways with entire satisfaction. Lathes also have multiple cutting tools, two, three and four. Locomotive driving wheel lathes, for example, can have its two wheels and two bearings machined simultaneously, though duplex machines are the general ones used. Shafting lathes have usually three tools operating, gun lathes, four, etc. Vertical boring mills have usually two heads. Turret lathes in their many modifications are a slightly different example of multiplying tools. The different tools are contained in one machine, but usually one tool operates at a time, the saving in time being effected by the extreme ease of changing from one tool to another. Screw cutting machines with multiple spindles are now universal, so that the price per operation is reduced to a minimum—what a difference between the time when every screw was cut in the lathe or by hand dies and present day practice, when, for example, the operator has to thread 15,000 half-inch bolts in a day to make a living

wage, as is the case in a Pittsburgh shop. The milling machine is another example of duplicating tools, though in a slightly different sense. The milling cutter may have twenty to thirty cutting edges, each doing its fair share of work and each is as distinctly an individual tool as the cutters in a boring bar, for example. Besides this a milling machine may have several heads. Milling machines have been productive of immense economy in the machine shop, not only in the decrease in time for the operation but also in facilities offered for milling any kind of profile.

The multiplying of cutting tools in a machine will always be more of special than general application. The tendency of engineering practice is towards specialization, which is eminently favorable to the multiplication of tools.

MULTIPLYING MACHINES.

Many non-automatic manually controlled machines can be replaced by semi-automatic ones, so that one man can attend to two, three or more of these machines; and, one step farther, many non-automatic or semi-automatic machines can be replaced by automatic ones, for which the only attention required is the intermittent feeding of a new bar from which the screws, nuts, bolts, etc., are automatically turned out. But, in addition, besides the economy in it, there is the advantage of obtaining uniformity of product and greater degree of accuracy. It is quite possible, however, to overstep the mark in installing automatic or semi-automatic machines, especially the former. They are only a paying investment when the number of pieces of one kind is large, so that the time taken to set the mechanism is small compared to the time the machine will be in operation. It is the balancing of capital and interest against saving in attendance.

Hand chipping should be replaced by pneumatic chippers, hand riveting by pneumatic or hydraulic riveters, hand filing by emery wheels or portable electric grinders, portable drills to replace the old ratchet. Planers should be supplemented by milling machines to cut down the number of operations, lathes

should be supplemented by grinding machines. Portable tools are usually thought of as being small and light, and the majority of them are, but sometimes the work is so large that it cannot be taken to the machines, and consequently the machine has to be taken to the work, necessitating large and heavy portable planers, drills, etc., such, for example, as were used in the shops of the Westinghouse Electric & Manufacturing Co. at East Pittsburg in machining large generator frames, some of these frames being laid out by means of a transit, as the ordinary method of straight edge, square and level, were insufficient.

In shops producing pieces by the thousand, such, for example, as bicycle factories, sewing machines, standard lathes and a thousand and one small articles of every description, the general practice is to install special machines for every individual operation, with always the result of cheapening cost.

Another imperative addition to all up-to-date machine shops is the traveling crane, which may be considered under the head of multiplying machines. Their value can hardly be overestimated, time and labor is saved to pay for the installation many times over. Practically all traveling cranes are electrically operated, and they are usually so equipped that there is motion in three planes at once. The use of the electric magnet for lifting in connection with these cranes should be made with reserve. It is, however, of much service in some places where the crane travel is small. Small electric or pneumatic jib cranes or suspended hoists should be installed wherever there is much lifting in one particular spot.

IMPROVING THE QUALITY OF THE CUTTING TOOL.

The discovery of the value of certain steel alloys is one of the greatest of the age in regard to machine shop practice. Its value is far-reaching, not only in greatly decreasing the time required for an operation but also in leading machine shop men to investigate all connecting problems, such as the strength and better design of machines, the time required for handling and chucking the work, etc. If, under old conditions, a certain operation in a machine required three hours'

time and one hour for chucking and handling, the idle time of the machine would be only 25 per cent. of the total, if the time of the operation were reduced by the use of high speed steels to one hour then the idle time would be 50 per cent., and some endeavor would undoubtedly be made to decrease time of chucking. There is a large amount of literature on the subject of these high speed steels, and some of the showings are little short of marvelous compared with former practice. This is especially the case under favorable conditions in experimental demonstrations. Under ordinary conditions the results are less startling, for the problem is not one of speed alone. High speed steel may not always be a paying investment; for example, a light job requiring relatively little time for cutting compared to time required for preparing and chucking; or, again, suppose, under ordinary conditions, a man has all he can do attending to two machines, the cutting time of one being just sufficient for the chucking time on the other, then any decrease in cutting time would be of small advantage. In general, the new steels cannot be used to the limit, first, because the present machines will not stand it and the general tendency is to retain present tools, working them to the limit instead of at once scrapping them, and, second, much of the work will not stand it on account of special shapes. The old carbon steels give better results, as far as service is concerned, on very light finishing cuts. But on the larger work, shafting, guns, wheel turning, big planing operations, etc., the advantage is enormous. These steels have increased the output of railroad shop machines 25 to 100 per cent., and in some cases even 200 per cent. There is still considerable experimental data to be obtained before the best results are obtainable from these steels, as the speed bears some relation to the depth of cut and the feed. The highest speed does not necessarily remove the greatest amount of metal in a given time. In general, a slower speed and heavier cut and feed is more efficient.

As a sample of what may be done in general practice there is given a table of results under new and old conditions in turning a pair of locomotive tires. These are average results and are not for a particular instance. They were reported in the

Proceedings of the American Railway Master Mechanics' Association for 1904.

UNION PACIFIC RAILROAD SHOPS.

COMPARATIVE TIME OF OUTPUT OF ONE PAIR OF DRIVING WHEELS.

OPERATION	TOOL STEEL Carbon Hrs. Min.	Air Hardening Hrs. Min.	High Speed Hrs. Min.
Setting tool, etc., throughout job ..	1 : 30	1 : 00	0 : 36
Grinding roughing tool	1 : 30	1 : 00	0 · 20
Grinding flanging tool	1 : 30	1 : 00	0 : 04
Roughing cut	8 : 00	5 : 00	1 : 00
Finishing cut	5 : 00	2 : 30	0 : 30
Flanging cut	2 : 30	1 : 30	0 : 30
Total labor.....	20 : 00	12 : 00	3 : 00

As a parallel to this, the average total time in the shops of the Pittsburgh & Lake Erie Railroad Co. per pair of wheels, under old conditions, using air-hardening steel, was eight hours; under new conditions four pairs per day, or 2½ hours per pair. This is not meant for a comparison of the two shops, as conditions may not be the same. But not the whole of this improvement is due to the tool steel. Much of it is due to better methods of driving and better facilities for handling the wheels. Many similar examples could be given. Later on in this paper reference will be made to some other results obtained in the P. & L. E. R. R. shops.

INCREASING THE SPEED AND EASE OF HANDLING THE MACHINES.

From the old hand driven or foot power tools to the line shaft belt driven shop was an immense stride, and as the machines themselves were improved so that some were all but human, it would seem that the limit had been reached. This was, of course, not true, even of the machine, and very much less so of the method of drive. The large belt-driven shops had become a perfect network of shafts, countershafts and miles of belting. These interfered greatly with the lighting

and general cleanliness. Another great drawback was the lack of speed variation. The cone pulleys and back gearing, or its equivalent, could give as wide a total speed change as was desired, but the steps were too coarse. The average increase of speed by means of the cone pulley was 50 per cent. It may be assumed the average loss of speed would be 25 per cent., that is, one-half the speed increment. If now it were possible to decide, within 10 per cent., the speed a tool will stand, and if a method of control were put in to give that speed increment, then the loss of speed would average only 5 per cent. The advantage in favor of a close speed range would thus be 20 per cent., and if the average time the machines were running were 50 per cent. of the workman's time, then the net savings would be 10 per cent. If the mechanic's wages were $3.00 a day, the saving would be 30c a day, or $100 a year per man.

The advantages of a motor-driven shop over a belt-driven one are now so universally accepted that no argument is necessary. All the technical magazines have had frequent articles on the special advantages of electrically driven shops toward getting cleaner, better lighted, easier handled shops and it would be but wasting time to repeat the arguments. The electric motor presents the opportunity of obtaining the close variations in speed that are so conductive to economy, and there are many different systems which will give, more or less accurately, the speed changes required. Until quite recently the multi-voltage system of control was undoubtedly the best, but owing to the great improvement or rather specialization of motors this system may probably be replaced entirely by the use of field controlled motors giving wide variations of speed. Although many engineers approve the use of the motor, yet they restrict it to the larger tools, but if it holds good for the larger tools why not also for the smaller? Do not exactly the same arguments hold? The value of the introduction of the motor was the reduction in the cost for labor. If any tool is driven by use of belt-driven cone pulleys, what difference does it make in the output of that machine whether the countershaft is belt-driven or motor-driven? None whatever. It may readily be proved that for any tool on which variation in speed is required,

that the installation of an individual motor drive with 10 per cent. speed increments will be an economical investment. The time is coming when practically every metal working tool, where speed changes or changes in material are required, will be, in an un-to-date machine shop, equipped with its own individual motor and at practically the price of the present tools. It is usually claimed that a group-driven system of motor drive is much cheaper than the individual motor drive, but such was not the experience in the shops of the Lake Shore Railroad, as was shown in an exhaustive report by the committee of the Master Mechanics' Association and published in their proceedings for the year 1903. An extract is given herewith,

LAKE SHORE AND MICHIGAN SOUTHERN RY.—COLLINGWOOD SHOPS.

COST FOR GROUP DRIVING.

11 group motors	$ 4,550.00
Wiring 11 motors @ $18.30	201.30
Wiring 202½ H. P. @ $4 80	972.00
Countershaft, line belt, pulleys, etc	6,667.00
Belting	3,881.00
	$16,271.30

ESTIMATED COST FOR INDIVIDUAL DRIVE.

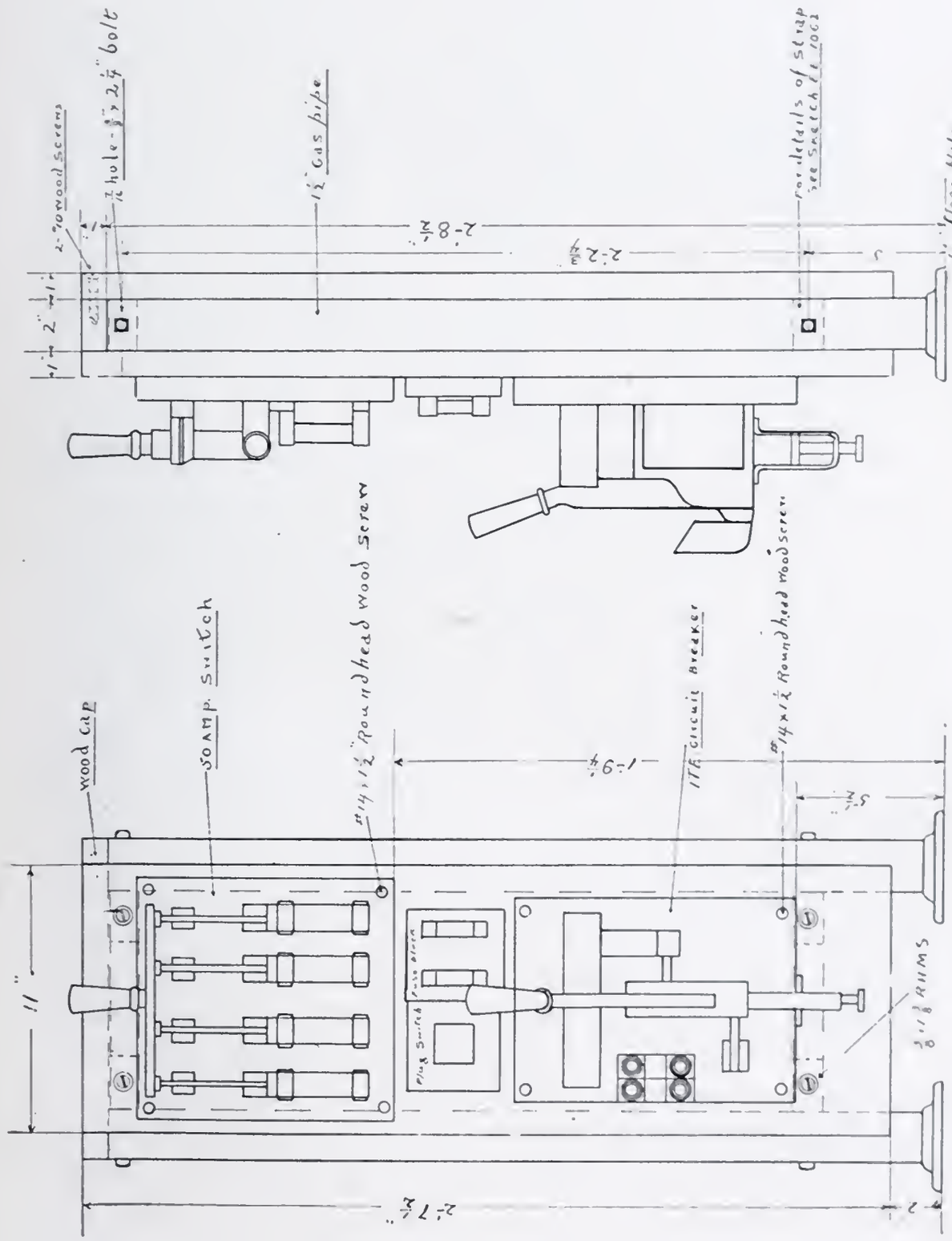
103 motors	$12,340.00
Wiring 103 motors @ $18.30	1,884.90
Wiring 242½ H. P. @ $5.40	1,164.00
	$15,388.90

This result may seem surprising, but it is even more favorable to the direct-driven estimate than it appears. The roof construction must be appreciably heavier when it is expected to support countershafting than would be the case if simply required to cover the building. Additional members must be incorporated, but this expense we are not in a position to estimate at present. Then no charge is made against belt-driven tools for belt shifters and the cost of applying the belting, which

for 103 tools is quite an expense." On the other hand the speaker thinks the estimate for the individual drive is somewhat low both in capacity of motors and cost of wiring. The whole report from which the above extract is taken is an excellent one and worthy of close inspection by anyone interested in shop equipment.

One argument often brought up against the old belt-driven shop was the great waste of power, and the same is brought up against the use of individual motors as against group driving on account of the lower efficiency of small motors, but the argument is not worth considering when the total amount of the power consumed is taken account of. The cost of power is very rarely 2 per cent. of the cost of the output in shops of any size. Suppose by the strictest economy 50 per cent. of the cost of power could be saved, yet the net saving would be only 1 per cent. During the year 1904 the total cost for power at the Pittsburgh & Lake Erie shops was slightly over one-half of 1 per cent. of the cost of the labor and material.

Some information concerning the motor equipped shop of the P. & L. E. R. R. at McKees Rocks may be of interest. The shops are compactly situated and consequently direct current could be used to advantage; the voltage in use is 250. For machine work, the multi-voltage system of drive is used and with excellent results. The voltages vary by steps of 40 from 40 to 240, with intermediate and additional steps obtained by means of field resistance. The controllers in use have 21 steps in forward motion, giving approximately 10 per cent. increments. Individual motor drive was carried to a much greater extent than in any shop previously put up, but experience has not shown that any mistake was made in so doing. In the machine shop only one small group of tools is driven from shafting. All the others have individual motors. The tools in the group above referred to are such tools as drill grinders, polishers, bolt threading machines, etc. In the wood working shops, however, group driving is the rule; individual motors are used only on the larger machines; in general in machines of this class no change in speed is required and therefore group driving is entirely satisfactory.



Circuit breaker used with individual driven machine tools.

One excellent feature of the electric installation is the entire absence of exposed wiring, and yet every foot of the floor of the big machine and erecting shop, 172x530 feet, is accessible. This is accomplished by running a tunnel 3 feet 6 inches by 4 feet the full length of the shop, and from it branch ducts 4x12 inches from side wall to side wall every 5 feet 6 inches. These latter were made part of the floor and were put in practically without expense. All the wiring in these ducts was put in after the floor was put down, loricated conduit being used.

In order to protect the machine not the motor, the motor is controlled through a fused switch and also a circuit breaker, The cut shows general type of panel used. This was varied to suit size of motor and type of control. Up to date there have been only three cases where the machine gave way, though all the machines have had severe work. The weak parts, chiefly gears, were replaced in these instances by heavier material, and no further trouble is expected. In obtaining speed variation, in a large number of machines it is impossible to obtain it entirely by the motor. Speed ranges of 50, 75 or 100 to 1 are not at all infrequent, such, for example, as changes given by the old triple or quadruple geared lathes. This is, in an electrically driven tool, taken care of by obtaining, say a 3 to 1 variation in the motor and the necessary number of change gears, each increasing the speed in proportion of, say 3½ to 1. A very common method of obtaining these changes is to use sliding or rocking gears. This the writer considers bad design; nothing but clutches should be used, for otherwise it is impossible to change from one gear drive to another except when the machine is idle, and then on the heavier machines only with difficulty, whereas with clutches the change can be made without stopping the machine. In the P. & L. E. R. R. equipment this point was absolutely insisted on despite the severe opposition of every tool maker. Magnetic clutches for the reciprocating tools were not used, as it was considered that the improvement in results would not be sufficient to warrant the expense, and also the clutches at that time were in a state of development. Better results may now be obtained and probably at lower cost.

The complete list of all motors installed numbers 83. This list of motors shows sizes as follows:

Number	Rating	Total H. P.
1	2	2
6	3	18
6	4	24
11	5	55
3	6	18
16	7½	120
1	9	9
10	10	100
1	13	13
13	15	195
3	20	60
7	25	175
3	35	105
1	45	45
1	60	60
83		1000

It should be noted that the rating is for full speed and voltage, not the actual horsepower obtainable at all times and not the horsepower required by the machines. The horsepower rating for the variable speed machines would be only 40 to 50 per cent. of the motor rating. The other motors around the plant would add about 450 horsepower and the cranes about 250 horsepower, bringing the total motor rating up to about 1700 horsepower. Of the 83 motors, 75 are used for individual drive and 8 for group driving, 5 of these 8 being in wood-working shops; 27 are constant speed and 56 variable speed motors. The total cost of these 83 motors was $20,275, or an average cost of $244.50, exclusive of mounting. The same motors could now probably be bought from 15 to 25 per cent. cheaper. The average horsepower of these 83 motors is 12.05.

During the year 1904, the average horsepower taken by all machine tool motors was about 200 during working hours, but all the tools listed above were not in operation. The average power consumption at present is about 300 horsepower, or about 30 per cent. of the horsepower rating of the motors. During the year 1904, the average power consumption of the machine tools was 17.3 per cent. of the output of power house; it was 38.71 per cent. of the total electric power; lighting was

24.9, heating motors 23.78 per cent. The electric power consumption of the machine tools including cranes and blast fan was subdivided as follows:

Variable speed tools	39.71%
Constant speed tools	26.80%
Blast fans	28.44%
Cranes	5.05%
	100.00%

The total cost of power for the machine tools, including the cranes, was $2,662.66, this does not include the maintenance of motors.

In addition to the shops being well equipped with motor-driven tools, there are at present in service seven cranes from 120 ton to 7½ ton capacity. Three more will be added shortly.

The capacity of the power house for electric work is 600 K. W. full load rating, or 750 K. W., with 25 per cent overload. There is space for one additional generator of 150 K. W. capacity.

The following few items are given concerning speeds of cutting. These are not given as maximum and are not special tests, but are every day practice, as previously stated.

P. & L. E. R. R. CO.—McKEES ROCKS SHOPS.

SAMPLE CUTTING SPEEDS.

No.	Machine Description	Wt. Removed Lbs. per Min.	Speed Ft. per Min.	Material	Remarks
10	Lathe	2.63	106	Cast iron	
10	"	2.33	44	Steel	
16½	"	1.69	170	"	
13	"	3.43	43	"	
20	"	4.2	54	Wro't iron	
14	Wheel Lathe	6.3	13.2	Steel	
23	" "	5.3	15.5	"	
51	Planer	3.2	30	Cast steel	
52	"	18.3	29	Cast iron	
62	Shaper	2.03	120	Brass	60 strokes, min.
39	Drill	0.52	74.5	Wro't iron	1¼″ drill
147	"	0.88	53.9	" "	1¼″ drill
33	Boring Mill	1.1	59.5	Steel	

Railroad shops are in general repair shops, so the weight of metal removed is not at all remarkable, compared to many tests which have been reported.

To show the excellent results obtained in the new shops the following figures may be noted. The shops were opened in February, 1904, but were not in full operation until some months later. It, of course, took some time to become used to new conditions, so that results for year 1905 would probably show a higher increase over year 1903.

Locomotives repaired	1903	64
" "	1904	145
Locomotives built	1903	None
" "	1904	10
New Fire Boxes	1903	5
" " "	1904	21
Cost of Labor	1903	$216,472
" " "	1904	$236,871
An increase of only 9.5%		
Credit for outside work..	1903	$ 4,800
" " " " ..	1904	$ 61,516

The force of men is now 25 per cent more than during 1903, but the output is very considerably greater. Formerly five to seven locomotives were overhauled per month, now from fourteen to twenty. Very much of the increase in number is due to the repairing of locomotives for other roads—Erie, Lake Shore, Pennsylvania and Union R. R.

The new shops are considered an excellent investment despite the heavy first cost, and it is estimated that they will have paid for themselves, including first cost and interest, in ten years or less.

DISCUSSION.

Mr. G. E. Freed, Mem. Eng. So. W. Pa.—What I have to say will deal more with the handling of material and distributing it through the shop than with equipment. What I have in mind is to take the raw material in at one end and put it out finished product at the other.

I think the machine tools should be arranged so that the material as far as possible goes in a straight line. There should be no going backward. I realize that it is not always practicable, especially where shops are built up in the air and elevators have to be used; but in a manufacturing establishment, and that is what I have in mind rather than a repair shop, we should get all we can out of the appliances we have, whether they be men or machines, and in order to do that we must handle the material just as little as possible, because every time we pick up a casting and truck it around the shop or up an elevator it costs money.

I know in a great many instances it is customary to have a general store room, a general stock room for the storing of castings and raw material; but then again I think there are instances where it is better to store the raw material where you are going to use it first. I have in mind a manufacturing establishment that has raw material all over the first floor, in bins handy to where it is going to be used. It saves a great deal of trucking, it saves a man's time going to the other end of the shop to get something to work on. His material is always at hand so there is a consequent saving of labor.

When that man is through with a piece have it ready for the next man, and so on as far as possible. I know I am treading on dangerous ground when I get away from the general storeroom, but there are certain lines of manufacturing that will admit of storing your raw material where it is going to be used first.

When the material is finished I would say, if practicable, have it handy to the assembling room or floor. Thereby the men get their pieces when they want them and do not lose time

waiting their turns at the storeroom door or window. We should not lose sight of the fact that the machine shop is run to pay dividends, and we should avoid all extra expense possible. While the shop may not look as nice as we would like it, while it may not be arranged as nicely as somebody else would like to see it, nevertheless it is arranged suitable for our requirements.

In regard to tools, it would seem best to have a tool for one operation and keep that tool busy as much as possible. There are circumstances under which it would be better to have a tool idle six months in a year, and then have it the other six months when you need it very badly, instead of having a tool that can be changed or arranged for five or six different operations, for just as surely as you want it for one operation it is fixed for another, and then something has to wait.

Mr. James H. Baker, Mem. Eng. So. W. Pa.—I fear that I differ from many of you so much that I might be treading on dangerous ground—perhaps no ground at all—there might be nothing under me. But I am going to say just one or two things, not in relation to the machine shop particularly, but on the principle Mr. Freed spoke of, the distribution of material when getting it in.

I had a forge where we avoided many new ideas, and I am not ashamed of it because we made money out of it. To give you an instance or two from my experience there, in this forge we weighed our material on the cars as it came in, then from an elevated track alongside of the forge we dumped that material where we wanted to use it, and there worked it up without further manipulation, either literally or on paper. If it was cut to lengths for a certain hammer we unloaded it just as close to that machine as we could. And if they were forgings that needed no further work after coming from the hammer they were inspected, counted and packed right where they were made. Mind you, I like system, but that system where if one wants a thing you never have to look a second time for it. I have balance sheets and precentage tables of different works I have been interested in, and I have been in forges that were thought to be a great improvement on the one I have just men-

tioned, but I have not anything that shows near as low incidental labor expense as the one I have referred to, and incidental expense is that thing we are all trying to avoid in our business.

Mr. H. H. Anderson, Men. Eng. So. W. Pa.—It is possible that there are a number here who have had experience in high speed steel. For myself I have had a good deal of experimental experience in the endeavor to find a tool steel that would cut high carbon steel. We tried various brands of air-hardening steel until we came to high-speed steel, where you have to heat the steel to such a point that it begins to flux. From these steels we have got good results.

Mr. G. M. Campbell—Carbon steel, the old steel that was in use for generations, was pure iron with a certain varying percentage of carbon in it. A step forward from the carbon is what is called air-hardening, or self-hardening steel. By using certain ingredients with the steel and heating that particular composition or compound to a certain temperature and cooling it, usually in air draughts, the tool would have a toughness, and, what is more, it would not lose its temper. The value of these steels is not in the trueness of their edge, or their strength, or toughness, but it is the temperature at which they work. The old carbon steels had to be worked at a relatively cool temperature, but a self-hardening steel could be worked at a very much higher temperature. Now come what are called the high-speed steels, which when they are being heated for tempering are heated so hot that the surface will actually run, and unless you heat them to about that point you can not get a good finish temper. In working with high speed steels the general instructions are not to use them above a red heat. That seems simply absurd to speak about using a cutting tool to red heat. But high-speed steels will actually work until in darkness they will pretty nearly show red. That is where the time is gained. In taking a heavy cut in roughing there is an immense amount of heat generated that must be got rid of. Part of it will go to the tool because the tool is right at the point of generation of the heat all the time. And the ad-

vanage of these steels is in their ability to stand the high temperature thus brought about.

The new high-speed steel is not considered the best steel for some purposes, a light cut or finishing cut, for example. As good a finished surface cannot be got with high-speed steel as with carbon steel. But wherever metal has to be removed, wherever heat is generated, that is where they have the decided advantage.

Mr. Geo. H. Neilson, Mem. Eng. So. W. Pa.—Not long ago, in the Pennsylvania Railroad shops at Altoona, I saw them flooding a cutting tool with a stream of water, and they claimed that the efficiency of the tool was very much heightened by keeping the heat away from it. The life of the tool was longer and they could do heavier work with it. I do not think that is a practice that is followed in very many works, but they do it there all the time.

Mr. G. M. Campbell—That is true with high-speed steels. It is simply necessary to keep down the temperature. A great many shops are using water simply for this purpose.

Mr. H. H. Anderson—I understand that at some shops in boring shells, even with water running on the high speed steel tools, it gets so hot that it shows a cherry red on the inside of the shell.

Mr. Geo. H. Neilson—Another point that is bound to come up will be the selecting of the various carbons in the high-speed steels to do various kinds of work, just as in the carbon steel.

A great many who make their living by selling high-speed steels will deny that, but I have made a great many tests, and you will find that the carbon that runs 0.8 will do work that a tool running 0.4 will not do.

At the Westinghouse Air Brake Co. they have a tool that will cut brass at any rate of speed they can drive it, but it won't cut cast iron. And the tool that will cut cast iron will not cut brass. The difference in the tools is only in the carbon. Everything else on analysis is exactly the same. But

the range of selection will not have to be anything like as great as it is in carbon steel.

I have seen lathe tools run as high as 2.25 carbon. It is very hard to handle. I have a lathe tool that will run 1.20 or 1.30. That is what you will usually run up against. That is a very hard steel to handle, but, like everything else, if you get it just right it will do the work. A soft steel, even of 0.4 carbon will not do the work. There is just the same thing in the selection of high-speed steels.

Mr. L. C. Moore, Mem. Eng. So. W. Pa.—I am at a loss to see how you can have 0.8 carbon and run the heat up to cherry red and at the same time run water on it.

Mr. Geo. H. Neilson—The influence of the alloy on the high-speed steel is in holding the carbon in solution and not letting it flow out. An ordinary carbon steel tool would burn out very quickly, but with the alloy holding it in solution it will not get away from it.

Mr. H. M. Wilson, Mem. Eng. So. W. Pa.—I think the steelmakers themselves realize that fact, because high-speed steels have to be made in different crucibles from ordinary carbon steel They do not use the ordinary crucible, because it causes a variation in the carbon and affects the steel.

Mr. L. C. Moore—I did not know until tonight that carbon is an element in high-speed steel. I thought that the tungsten and the other elements were the ones that did the trick.

Mr. Geo. H. Neilson—I read in a paper a while ago that high-speed steel had absolutely no carbon in it. The paper was written by a man who had used thousands of dollars' worth of high-speed steel in his shop, yet did not know there has never been high-speed steel without carbon. The influence of carbon, from the experience I have had with it, makes almost as much difference in a high-speed tool as in a carbon-steel tool, and if anybody has had a different experience I would like to hear from them.

Mr. G. F. Freed—I have either been told or I have read in one of the circulars that high-speed steel is just as free from carbon as they can make it, depending on the alloy for its prop-

erty, and that what carbon is in the steel is from the crucible or gets it during the process of manufacture, but they avoid it as much as possible.

Mr. H. H. Anderson—I think a great many agents in selling high-speed steels have declared that the great idea is to bring the tool in tempering to a flux so that the alloys would come to the cutting edge and eliminate all the carbon possible in the tool. They say they have it down to .4, but they do not claim to have excluded it entirely.

Mr. Geo. H. Neilson—I have seen an analysis made of nearly every high-speed steel put on the market up to within the last six months, and every one of them showed carbon and a strong percentage of carbon.

Mr. L. C. Moore—How do you account for the fact that with a carbon of .8 you can cut a locomotive frame and run cold water on the edge of the tool, and still have the tool stand? I mean with self-hardening steel.

Mr. Neilson—They don't let it get hot enough to crack it, is the only way I can explain it. The only place I have seen it done where I asked anything about it was at the Altoona shops, and they didn't have it anything like that hot, because the water turned on the steel did not steam at all.

Mr. L. C. Moore—I do not think it is always essential to a piece of steel that it should contain a certain percentage of carbon. I know the common idea is that if we have not carbon we have iron. Yet in my practice in my younger days I have known many brands of steel that were absolutely free from carbon, yet we knew they were steel, as we term it. They were made up of a combination of elements, but we were never able to determine just what they were. No two chemists making dozens of analyses from the same test specimens would get an average of nearer than 8 and 20. Their variations would be that great in percentage. And yet those steels were so tough that you could do almost anything with them except cut with them. A cold chisel would cut it freely, yet you could punch a hole in it and draw two miles of wire through the hole without the hole giving way more than 1-1000 of an inch. I never

was able to learn what the elements in it were, but there was not a trace of carbon in it.

Mr. Arnold Stucki, Mem. Eng. So. W. Pa.—Mr. Campbell has mentioned day labor, piece work and the premium system. I would like to have the latter plan explained a little more in detail. We all know that day labor does not do justice to either the man, the machine or the employer. The next best thing is piece work. It is more satisfactory, inasmuch as the workman feels that he is working for himself.

But often it is impossible to adjust the price of certain work just right, and in order to protect the employer a certain limit is set for each man, above which he is not allowed to go per day. What is the consequence of this? It is natural, that each man tries to get as high a rating for each piece as possible, and if he finds that he is going to overstep the limit he either slacks off in his work or stores the surplus for a future "rainy day." In either case the output of the machine is reduced, and even the "card system" does not remedy this.

For this reason the premium system has been introduced. It is the piece work system, extended in such a way that the workman, after reaching the regular limit, is not stopped. Instead of this he gets a certain percentage of what he makes extra. This way the employer obtains the maximum amount of work which the machine is able to perform, and I know of cases where this system works very well.

Mr. G. M. Campbell—In general Mr. Stucki's statement is quite correct as to what the premium system is as it is ordinarily understood. There are different forms of it. Usually a man is guaranteed a certain wage, just the same as if he were working on day work, and he gets that no matter whether he works out the amount of material stipulated or not. If, for example, he gets 30 cents an article and he has to put out 10 for a day's work, if he only gets out 9, that is $2.70, yet he gets his $3.00 because he is guaranteed that. But if he gets out more than 10 he gets a certain percentage on the excess, which varies in different shops, usually a certain percentage up to a certain overoutput and a certain other percentage beyond that.

In general all these schemes sooner or later come down to pretty near day work. In a certain locality there is generally a certain price, which is more or less a living wage, and sooner or later, no matter what system is in force, it will come down to what is called a living wage. It comes about through new manufacturers. An old established firm, having a business, installs a system of premiums, and fixes certain rates. But another manufacturer comes in. He is not bound by that first rate, and fixes a lower rate to suit himself. If there is an abundance of labor that man with his lower price can put out a cheaper product, and the old manufacturer must meet the competition. So with all these systems; the men do not like them because they know they have to work harder to get a living wage.

Mr. L. C. Moore—I would like to ask Mr. Campbell if he does not believe that improved machinery and improved facilities have done more toward increasing production than premium systems and schemes of that kind?

Mr. G. M. Campbell—I think it is the case, though they all work together. The whole thing is so interwoven that it is pretty hard to pick out which is which.

Mr. G. E. Freed—My experience has been that the men prefer piece work to premium work. They are generally averse to taking one-half the increase; they want it all, and they prefer to stick right to the piece work.

Mr. H. H. Anderson—Very frequently the quality of the work is neglected if it is possible to increase the output thereby, and the increase is at the expense of the machinery. They will strain every point to get the greatest possible output, and at the same time neglect the machine, which ought to receive the most attention to enable them to get the necessary work out, while with day work you can rest assured that they will pay a great deal more attention to the machine than they would on piece work, and the keeping up of their tools, etc.

Mr. Stucki—In regard to working two tools per machine, I fully appreciate what Mr. Campbell has said, and I wish to emphasize also that two tools are very much easier on the ma-

chine and enable us to do the work more accurately. It, for instance, is a well known fact that it is impossible to bore an absolutely true hole on a boring mill with only one tool.

For a similar reason the milling tools are gaining in favor every day. Besides this they are especially economical, because they never return, such as planers do, and this fact alone explains the great saving in time affected by milling tools.

PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

VOL. XXI DECEMBER, 1905 No. 9

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The 259th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's House, 410 Penn Avenue, Pittsburg, Pa., Tuesday, November 21, 1905, at 8:15 P. M., President Samuel Diescher in the chair, with 60 members and visitors present. The following gentlemen registered:

MEMBERS.

Albree, Chester B.
Anderson, H. H.
Baltzell, William H.
Barnsley, Geo. T.
Branson, C. R.
Campbell, G. M
Cruikshank, J. W.
Davies, Thos. P.
Dickson, W. E.
Dittmar, Edward J.
Flanagan, Gerald E.
Haggart, C. N.
Hawley, W. C.
Hegman, W. H.
Hoerr, Alex. L.
Jennings, F. R.
Johnson, Thos. H.
Kintner, S. M.
Klindworth, J. L.
Knowles, Morris
Leland, E. D.
Lester, Bernard
Lewis, Harry J.
Linton, Robert L.
Moore, C. S.
Moore, L. C.
McFail, C. B.
McMullin, F. V.
Riggs, Edwin H.
Rice, Francis S.
Schatz, Fred C.
Schluderberg, Geo. W.
Stutz, C. C.
Wilson, W. C.
Whited, Willis
Wilkerson, T. J.
Winter, F. W.

VISITORS.

Curtis, E. H.	Lea, H. J.
Duemler, Paul E.	Millenhoeff, K. C.
Klein, Maurice	Parsons, W. C.

The minutes of the last meeting being in print, and there being no objections, their reading was dispensed with.

The report of the Board of Direction was read recommending for membership eleven applicants.

On motion the Secretary was instructed to cast the ballot of the Society for their election.

The Secretary reported; That at the September meeting of the Society, the matter of revising the Building laws of Pittsburg was referred back to the Board of Direction. The Board are investigating but have not received sufficient information to warrant a report at this date.

The President read the report of the Nominating Committee as follows:

President, Julian Kennedy,
Vice President, J. K. Lyons.
Directors, { E. K. Morse. / A. R. Raymer.
Secretary, F. V. McMullin.
Treasurer, A. E. Frost.

Mr. Barnsley reported that on November 28, 1905, the Society was the guest of the Mackintosh-Hemphill Company on an excursion to the Carnegie Steel Company's works at South Sharon; and on November 18, 1905, they were the guests of the Bureau of Filtration and of the contractors for the new filtration plant of Pittsburg.

On motion, the thanks of the Society were extended to the Mackintosh-Hemphill Company, Carnegie Steel Company, the officers of the Bureau of Filtration, the T. A. Gillespie Company, and the West Penn Railroad Company for courtesies extended.

Mr. Barnsley reported that a Smoker would be held at Hotel Schenley, December 9th, 1905, which will be the second

and last one for the year. Members are urged to attend and notify their friends.

A paper on "Producer Gas and Gas Producers," was read by Samuel S. Wyer. On motion a vote of thanks was extended to Mr. Wyer.

After discussion the meeting adjourned at 10:45 P. M.

F. V. McMULLIN,
Secretary

NEW MEMBERS.

NAME,	OCCUPATION AND ADDRESS.	ENDORSED BY
HARRY F. AFFELDER,	Draftsman, Westinghouse Machine Co., E. Pittsburg, Pa. h. 1230 Sheffield St,, Allegheny, Pa.	Louis J. Affelder, E. S. McClelland, C. B. Connelley.
G. R. McALEENAN,	Superintendent, The Jas. Lappan Mfg. Co. 20th and Pike Sts., Pittsburg, Pa,	H. Gulick, Jr., W. L. Shaw, F. V. McMullin.
HERMAN BACHARACH,	Mech. Engineer, With Dilworth, Porter & Co. h. Fourth and Bingham Sts., Pittsburg, Pa.	Ludwig Hommel, R. M. Morganstern, Henry W. Fisher.
GEO. H. DEIKE,	Mining Engineer, Creighton Coal Works, Creighton, Pa.	H. K. Hitchcock, O. C. Stutz, J. W. Cordes.
HEWITT J. NEALL,	Engineering Dept., Westinghouse Elec. & Mfg. Co., E, Pittsburg. Box 911 Pittsburg, Pa.	Henry D. James, R. S. Feicht, S. M. Kintner.
EDWARD U. SMITH,	Draftsman, American Bridge Co. Box 159 Ambridge, Pa.	P. Brynn, C. N. Haggart, James K. Lyons.
JOHN D. STEVENSON,	Third Asst. Engr., Bureau of Filtration, Pittsburg, Pa. h. 120 First Street, Aspinwall, Pa.	A. D. Neeld, M. M. Maneese, M. Knowles.

MONTHLY MEETING OF BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at 410 Penn Avenue, Pittsburg, Pa., November 18, 1905, at 8:00 P. M.

Present, Messrs. Diescher, Flanagan, Kintner, Lyons, Whited, Barnsley, Knowles and Secretary.

The following resignations were accepted:

W. A. Edeburn, Wm. Piez,
Bailey E. Hobson, Elliot M. Sergeant,
Arthur E. Pew, John M. Rayburn,
S. B. Whinery.

The death of Arthur Capen was reported.

Treasurer's Report:

Building Fund,	$ 320.58
Permanent Fund,	220.20
Checking Account,	1,160.61
Total,	$1,701.39

Secretary's Report:

Membership, November 18, 1905, 946.	
Collections, Oct. 14th to Nov. 18, 1905,	$ 359.35
Previously Reported,	8,613.60
Total, 1905,	$8,972.95
Total, Nov. 18, 1904,	$6,043.93
Increase, 1905,	$2,929.02
Payments to November 18, 1905,	$7,069.00
Bills were paid aggregating	588.95
Total Payments for 1905,	$7,657.95

On motion the Secretary was directed to send out a circular letter December 1st, to members who had not paid 1905 dues, requesting them to forward to the Board, not later than

the December meeting, a statement of any extenuating circumstances by reason of which their expulsion should not be recommended.

The Publication Committee reported that up to date $723 worth of advertising had been secured.

The Committee on By-Laws reported a new charter and the Secretary was directed to have a copy of the new charter sent to each member of the Board of Direction.

The meeting adjourned at 11:00 P. M.

F. V. McMullin,
Secretary

SPECIAL MEETING OF BOARD OF DIRECTION.

A special meeting of the Board of Direction, held at 410 Penn Avenue, November 21, 1905, at 7:40 P. M., for the purpose of hearing report of the Reception Committee on the proposition to serve lunch after the Society meetings.

Present—Diescher, Flanagan, Kintner, Whited, Knowles, Barnsley and Secretary.

Mr. Barnsley, on behalf of the Reception Committee, reported that the lowest price for which lunch could be served was 60 cents per person.

On motion report was laid on the table.

On motion meeting adjourned at 8:15 P. M.

F. V. McMullin,
Secretary

CHEMICAL SECTION.

The regular monthly meeting of the Chemical Section was held in the Society House, 410 Penn Avenue, November 23, 1905, with the Pittsburg Section of the American Chemical Society.

The Chairman and Vice Chairman being absent, the meeting was called to order at 8:15 P. M. by the Secretary. On motion, Mr. A. L. McKenna was elected temporary chairman. Thirty-eight members and visitors were present.

The chair appointed the following as a committee to nominate officers for 1906, with instructions to report at the December meeting:

F. C. Phillips, Chairman,
H. C. Babbitt,
H. E. Walters.

Dr. J. H. James described the courses in chemistry given at the Carnegie Technical Schools. Mr. Charles S. Bradley spoke on some phases of industrial electrochemistry.

On motion, the meeting adjourned at 10:00 P. M.

HARRISON W. CRAVER,
Secretary C. S.

MECHANICAL SECTION.

The regular monthly meeting of the Mechanical Section was held at 410 Penn Avenue, November 14, 1905, at 8:30 P. M., with Chairman H. H. Anderson in the chair and 30 members and visitors present.

As the Secretary was absent no minutes of the previous meeting were read.

There was a discussion on "Bearings" participated in by the following gentlemen: Stucki, Klindworth, Anderson, W. M. Davis, Kingsbury, Cronemeyer, Campbell, Ruddiman and Flanagan.

On motion, the Chair appointed A. Stucki, G. M. Camp-

bell and H. C. Cronemeyer a committee to nominate officers for the Section for the coming year.

It being announced that Mr. Fitts, who had acted as Chairman of the Program Committee during the past year, was about to remove from Pittsburg, on motion a vote of thanks was extended to him for the efficient manner in which he had conducted the program work.

On motion the meeting adjourned at 10:30 P. M.

STRUCTURAL SECTION.

The regular monthly meeting of the Structural Section was held at 410 Penn Avenue, November 28, 1905, at 8:30 P. M.

The meeting was called to order by Vice Chairman Robt. A. Cummings, 21 members and visitors being present.

Minutes of the last meeting were read and approved.

Under announcements the Secretary announced the Nominating Committee to nominate officers for next year:

Willis Whited, Chairman,
F. L. Garlinghouse,
F. Z. Schellenberg,
L. J. Affelder,
J. N. Chester.

A paper entitled "Conditions Governing County Road Construction", by Fred W. Patterson, member, was read by the Secretary in the absence of the author.

The discussion was taken part in by the following gentlemen: Cummings, Whited, Capt. Martin, Babbitt, Davis, Judd, Covell, Wilkerson, Campbell, Tenney, Danforth, Flanagan, Knowles and McEwin.

Meeting adjourned at 9:50 P. M.

T. J. Wilkerson,
Secretary S. S.

A. B. CAPEN.

Arthur Bryan Capen was born in Mattoon, Ill., July 25, 1862. While a young man he became connected with the Babcock & Wilcox Boiler Company and for some years past had represented them in Pittsburg.

He became a member of the Society April, 1900

His death came very suddenly while stopping at the Hotel Manhattan, New York, October 28, 1905. Interment was at Mattoon, Illinois.

THE USE OF AMMONIUM PERSULFATE IN THE DETERMINATION OF CHROMIUM IN STEEL.*

† HARRY E. WALTERS,

Member.

Ammonium persulfate is used as a reagent for oxidizing chromium in steel in a method described by F. Ibbottson and R. Howden (Chemical News, vol. 90, pp. 320-321). After oxidation the chromium is precipitated as lead chromate, filtered and determined volumetrically.

The writer has been using a method for some time in which the same salt is used, advantage being taken of the fact that in the presence of sufficient silver nitrate both the chromium and manganese are completely oxidized and can be determined volumetrically without previous precipitation. The method as outlined is applicable for ordinary chrome steels, but not for tungsten or molybdenum steels, as some of these steels contain a carbid of chromium insoluble in sulfuric acid. This difficulty can be overcome by filtering the insoluble carbid, burning and fusing with a small amount of sodium carbonate and adding to the main solution. This, however, would prolong the operation but would still be an advantage over the methods now in use.

METHOD.

Weight 125 grammes of the sample into a No. 3 Griffin beaker, add 35 c.c. sulfuric acid (1 acid to 5 water) warm until sample is in solution and add a small amount of ammonium persulfate to oxidize the iron and carbonaceous matter, dilute to 100 c.c. and add 40 c.c. silver nitrate solution (0.16 gram of

* Read before the Chemical Section, Oct. 19, 1905.

† Laboratory United Engineering & Foundry Company, Lincoln Foundry Department, Pittsburgh, Pa.

the salt), now add an excess of ammonium persulfate (5 to 7 grammes) and heat to boiling. Boil about five minutes to destroy excess of persulfate, cool and transfer to a 500 c.c. calibrated flask, dilute to mark with water and mix thoroughly.

Pour 100 c.c. (.25 gramme) into a 100 c.c. calibrated flask; the remaining 400 c.c. (1 gramme) are transferred to a beaker, a measured volume of ferrous sulfate added, and the excess titrated with a standard solution of permanganate until a pink color is obtained.

The number of cubic centimeters of the permanganate solution used subtracted from the number required for the volume of ferrous sulfate added, will give the volume of permanganate used by the chromium and manganese.

The contents of the 100 c.c. calibrated flask are transferred to a porcelain dish and titrated with a standard solution of sodium arsenite until the color is bright yellow. The number of cubic centimeters of the arsenite solution used, multiplied by the value of the solution in manganese, will give the amount of manganese present.

The volume of permanganate used by the chromium is found by calculating the amount of manganese found to the equivalent number of cubic centimeters of the permanganate solution and subtracting this number from the volume of the permanganate used by the chromium and manganese. The number of cubic centimeters found to be used, multiplied by the value of the permanganate in chromium, will give the amount of chromium present.

Example—Let us assume that the chromium value of each cubic centimeter of the permanganate solution equals 0.001 gramme, and the manganese value 0.000633 gramme; now if 50 c.c. of the ferrous sulfate solution equals 49 c.c. of the permanganate solution, and the sample after oxidation and addition of 50 c.c. of the ferrous sulfate solution requires 13 c.c. of the permanganate solution, then 49 c.c. minus 13 c.c. equals 36 c.c. or amount used by chromium and manganese.

If the sample should show 0.38 per cent. manganese by the arsenite titration, then 0.0038 divided by 0.000633 equals 6, or

the number of the cubic centimeters of permanganate solution equivalent to the per cent. of manganese found.

36 c.c. minus 6 c.c., or 30 c.c. multiplied by 0.001 equals 0.03 gramme or 3 per cent. chromium.

REAGENTS

Sulfuric Acid—A mixture of one part concentrated acid and five parts water.

Silver Nitrate—Four grammes of the salt are dissolved in one liter of water.

Ammonium Persulfate—The salt should be slightly moist.

Sodium Arsenite—The solution is prepared as recommended by Blair (Chemical Analysis of Iron, 5th Edition, pp.121), The solution is standardized with a chrome steel of known manganese content so that the direct reading will give the percentage of manganese. Mixtures of pure chromium and manganese solutions may also be used.

Permanganate Solution—The solution is made by dissolving 1.82 grammes of pure potassium permanganate in 1 litre of water.

Ferrous Sulfate Solution—The solution is made by dissolving 22.5 grammes ferrous ammonium sulfate in water, adding 50 c.c. strong sulfuric acid and diluting to 1 litre.

It is unnecessary to have this exactly equal the permanganate solution, as a constant volume is used and the solution loses its strength. It is only necessary to find the volume of permanganate equivalent to the volume of ferrous sulfate used, and this should be done every day.

The permanganate may be standardized by getting the iron value or by the use of a pure chromium salt.

If the solution is standardized against iron the chromium value is found by the equation.

168 : 52.14 : : iron value : chromium value

and the manganese value by the equation.

280 : 55 : : iron value : manganese value.

If the solution is standardized with pure chromium salt the manganese value is obtained by the equation.

260.7 : 165 : : chromium value : manganese value.

REMARKS.

In case the samples should run high in chromium the ferrous sulfate solution could be made stronger.

The permanganate solution should be allowed to stand several days before standardizing.

In case an appreciable amount of vanadium is present in a sample it will be necessary to determine the manganese by the bismuthate or Ford's method.

The moist ammonium sulfate is recommended on account of difficulties encountered when using the dry salt in determining lead and manganese in previous work. These difficulties were surmounted when the moist salt was used.

In using the method for tungsten steels some tungstic acid separates, but this does not seriously interfere with the titration.

The following results were obtained on some chrome steels and pure solutions of iron, chromium and manganese.

Number.	Percent. chromium taken.	Percent. found.	Percent. mang. taken.	Percent. found.
1	4.00	3.98	0.08	0.09
2	4.80	4.82	0.40	0.40
3	1.56	1.53	0.24	0.23
4	3.60	3.57	0.80	0.81
5	5.10	5.12	0.50	0.49
6	8.00	8.03	0.32	0.32

Steels.	Percent chromium.	Chlorate method, Percent. mang.	Percent. chromium.	Persulfate method, Percent mang.
1	1.50	0.35	1.51	0.36
2	2.88	——	2.85	0.14
Tungsten	3.50	0.12	3.49	0.13
Molybdenum	5.69	0.81	5.71	0.83

I wish to acknowledge my indebtedness to Mr. T. D. Rodgers of this Laboratory for the careful manner in which he has carried out these experiments.

*BEARINGS.

A TOPICAL DISCUSSION.

Mr. A. Stucki, Mem. Eng. So. W. Pa.—I will simply mention some average figures regarding composition, pressure and design, which have been found to give good results in actual practice and which are being adhered to on locomotives and cars.

Of late solid phosphor bronze driving boxes are largely used and are of about the following composition: Copper 79.7%, lead 9.5%, tin 10%, phosphorous not over 0.8%. Although the first cost of these heavy boxes is large, it is offset by getting almost the original value in the scrap.

In the car bearings a similar composition is used, except that the lead may run a little higher. The composition is copper 78—80%, lead 10—13%, tin 9—11%, impurities including zinc, iron, etc., not to exceed .75%. One large railroad has obtained very good results with a bearing slightly lower in tin, the composition being as follows: copper 76.75%, lead 15%, tin 8%, phosphorus .25%. All these car brasses are bored out and then lined with a soft composition which is poured in place after the bearing has first been heated. This lining consists of antimony 3—5%, lead 94—96½, tin ½—1½%.

The lining was originally $\frac{3}{32}$ inch thick in the center tapering to nothing at the sides, the idea being to give the bearing a chance to run smooth gradually without heating, and for the same reason the cars on the first trip are loaded to only half of their normal capacity, if loaded at all. About two years ago this lining was increased by some railroads to ⅜ inch thickness in the center, and the results have been very

* Meeting Mechanical Section, November 7, 1905.

satisfactory, so much so that many roads follow this practice today.

The pressure per square inch of projected area varies greatly with the number of revolutions per minute, the nature of the bearing, the lubricant, etc. For instance, the bearing on a main rod of a locomotive is usually subjected to a pressure ranging from 1800 to 2100 lbs. per square inch. This seems very high, but the fact that any one point of the bearing is exposed to the pressure but half the time, may explain why good results are obtained. Nevertheless, this pressure is reduced, if it can be done conveniently, and for this reason the bearings of the parallel rods are designed to carry only 50—75% of this pressure.

In a driving box the pressure per square inch is about 230 lbs., the speed may run up to possibly 300 revolutions per minute, and the diameter of the bearing being as large as 9 inches or more gives a high circumferential speed. On the locomotive truck boxes the number of revolutions per minute is naturally greater and the pressure per square inch of bearing smaller.

On freight cars it is not considered wise to go above 350 lbs. per square inch. Under passenger cars the same axles are often used as for freight car equipment. However, the load and consequently the pressure on the bearings is smaller, the proportion being as 18 to 15, which will bring the pressure on the passenger car journals below 300 lbs. per square inch.

The proportion between length and diameter has to be watched carefully. In order to reduce heating as much as possible the circumferential speed has to be reduced. This is accomplished by making the diameter small. But to keep the pressure within the proper limits it would be necessary to make the bearing very long. Here is the other extreme, as a journal of such dimensions would not have the necessary strength and allowance for wear, and we simply have to choose the happy mean. On all standard car axles of today this proportion of length divided by diameter is about 1.8.

One of the most important items entering into this ques-

tion is the lubrication. As a rule there are oil cellars, or waste receptacles, forming the lower part of the boxes. These cavities are filled with waste, which is first saturated with oil, and it is expected that the resilience of the waste will keep it in constant touch with the axle. In car journal boxes such waste is easily supplied with additional oil, in fact the box is easily responged, and in this way the results have been very satisfactory. On locomotive driving and truck boxes additional oil cavities on top of the boxes are provided for, which can easily be filled. The oil then passes first over the bearings and is finally absorbed by the waste in the cellar below.

On the bearings of the main and parallel rods the presence of waste receptacles is out of the question, and oil cups are employed instead. Finely adjusted needle valves are frequently used to regulate the flow of oil, but of late automatic feed valves have gained favor. These valves are raised off their seats by the centrifugal force once every revolution, and if the locomotive stops the oil ceases to flow. The lift of these valves is usually adjusted by a nut locked set screw, and it is needless to say that such a valve has many advantages. I also know where similar oil cups have been applied to the underside of the main rod bearings, feeding additional oil from underneath by centrifugal force so as to overcome heating, and it was reported, that the trouble, which existed before, was completely overcome by this arrangement.

Mr. H. H. Anderson, Mem. Eng. Soc. W. Pa.—I do not see the use of an oil cup on the bottom of a connecting rod. It seems to me that the cup on the top would give all the lubrication that is necessary.

We made some experiments on roll neck brasses and tried various compositions. The composition which gave the best results was: Copper 85, tin 7, lead 7, zinc .75, phosphorus .25, but even with a good composition the proper mixing has a great deal to do with the result attained.

Mr. J. L. Klindworth, Mem. Eng. Soc. W. Pa.—A good bearing for roll necks is made by copper, or brass, strips let into the casting and babbitted, one on the bottom and one on

each side, at say, 45° on each side. For tin plate and sheet mill rolls of course you cannot use babbitt as it would soon melt, they use bronze for those bearings.

Mr. Anderson—That would be all right with a cold neck brass, but if you have a hot neck brass you need something to resist heat as well as pressure.

Mr. Wm. M. Davis, Mem. Eng. Soc. W. Pa.—Mr. S. B. Ely has told me that the probable pressure on the brass, or neck, of sheet mill rolls when under stress, as when rolling sheet steel with the ordinary size roll neck, with the pressure at its maximum, is about 1000 to 1500 lbs. per square inch. Of course the pressure on a roll neck, especially in sheet mill and tin plate practice, is only for an instant, and then the surface travel, or speed, of the neck is very slow. Those rolls make 28 to 30 revolutions per minute and their diameter is about 18 inches. They have to be very large to stand the sudden shocks without breaking.

The P. & L. E. R. R. are using grease on all their rod connections. This grease is very hard, almost like bar soap. It is packed into the cup and a plunger screwed down on it. They give it a turn with a wrench before going out and I believe that lasts them the run. The temperature rises to a certain degree, which is below the danger point, but does not rise above it. Mr. Redding, of the P. & L. E. R. R., says they have been very successful with it and it gives very economical results. The cheapness of their lubrication is surprising, it costing about 4¾ cents per thousand miles per car for freight cars, and from 3 to 3½ cents per 1000 miles for passenger cars. It would not do to use grease in the car journal boxes as that would increase the friction load, especially if the grease became chilled.

Mr. H. C. Cronemeyer, Mem. Eng. Soc. W. Pa.—Although not correct by any means, as will be shown later, it is generally assumed that the load on a bearing is uniformly distributed over the projected area, that is, the length multiplied by the diameter.

Hence in proportioning a bearing we have: $P = l\ d\ p$.
Where P = total load,
p = pressure per sq. inch of projected area.
l = length of bearing,
d = diameter of bearing.

The following values of p are given by Prof. Bach, from whose excellent work much of the following data is taken:

Crucible Steel on crucible steel, hardened and polished	2100 lbs. per sq. in.
Crucible Steel, hardened, on bronze	1250 " " " "
" " unhardened, "	850 " " " "
Wrought iron, dense and polished, on bronze	570 " " " "
Wrought iron, not very good surface, or cast iron, on bronze	425 " " " "
Same on cast iron or bronze	350 " " " "
Wrought iron on lignum vitae with water lubrication	350 " " " "

For special cases values are given as follows:

Crank pin and cross head pin of stationary engines of moderate speeds	850-950 and 1000-1150 lbs. per sq. in. resp.
Same for high speed engines	550 and 700 lbs. per sq. in. resp.
For main bearings of stationary engines	200 to 350 lbs. per sq. in.
Crank pin and cross head pin of locomotives (Allowing for greater wear)	1400 and 2100 lbs per sq. in. resp.
Crank pins of punches and shears	2800 lbs. per sq. in. and more.

A theoretical investigation of the pressure distribution shows that the load is not uniformly distributed over the bear-

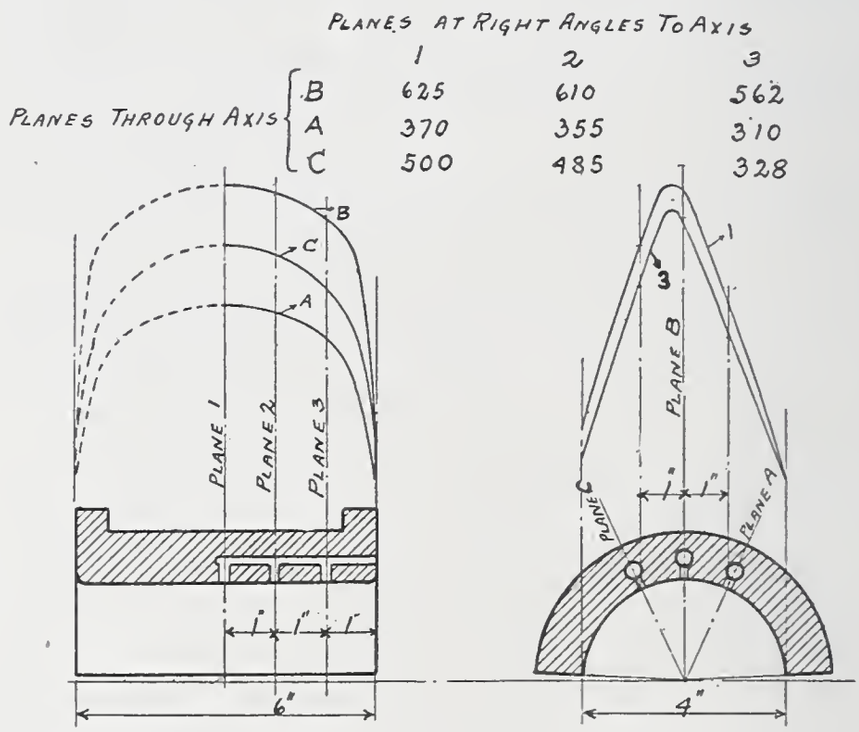
ing and that the pressure per surface unit is given by the formula:

$$P = \frac{4}{\pi} \frac{P}{ld} \cos \alpha$$

Where α is the angle which the line of the load makes with the radius to the element of surface under consideration. The maximum unit pressure is in line with the direction of load and is equal to $\frac{4}{\pi} \frac{P}{ld}$, or about 25% greater than the average pressure.

An experiment by Mr. Tower, the result of which is described in The Engineer, 1884, page 434, shows that there is a further deviation from uniform distribution of load.

A bearing 6 inches long and 4 inches diameter was loaded with 8000 lbs. giving a pressure of 325 lbs. per sq. in., assuming



uniform distribution of load. The actual pressures were obtained by drilling 9 holes into the bearing, and then measuring the pressure of the lubricating oil at these points by means of a pressure gauge.

These holes were spaced in 3 axial planes, A, B and C; Plane B through the centre of the bearing, plane C 30° ahead

in the direction of rotation and plane A 30° behind. Assume now these planes intersected by three other planes at right angles to axis, plane 1 at the centre of the bearing and planes 2 and 3 spaced 1 inch and 2 inches away respectively.

The pressures obtained at these 9 points are given on the sketch. By plotting these pressures in curves it will be seen that the pressure falls away toward the ends of the bearing, and is maximum at a point in the middle, a little forward of the centre in the direction of rotation, and that this maximum is 90% greater than the average as it is generally calculated.

Mr. J. H. Smith, Mem. Eng. Soc. W. Pa.—Is that shaft under flexure?

Mr. H. C. Cronemeyer—It might have been but I do not believe such was the case, although the experiment was carried through with holes drilled in half of bearing. It was merely a bearing fixed up for the purpose of the experiment so as to eliminate all other conditions. But it is unquestionable that flexure has a great deal to do with it, and for that reason the bearings of heavy engines are made flexible.

To guard against overheating, Prof. Bach proceeds under the assumption that no excessive rise in temperature will take place if the work of friction per unit area does not exceed a certain figure derived from experiment. The work of friction per unit area, W, is given as follows:

$$W=\frac{p.\ f.\ n.}{180\ \ 1}$$ where p=total load on bearing.
f=coefficient of friction.
n=number of revolutions of shaft.
1=length of bearing.

This work of friction, converted into heat, must be less than a constant C, the value of which for various conditions has been derived from experiment.

The condition now is $\frac{p.\ f.\ n.}{180\ \ 1} \leq C$ or $1 \geq \frac{p.\ f.\ n.}{180\ \ C}$

The values of C are as follows:

For crank pins—steel on bronze or babbitt.....	C= 58-90
The same—with exceptionally good work.....	C=140
Main bearing of engines.....	C= 23-62
Axle bearings of passenger coaches.....	C=124
Locomotive axle bearings.....	C=230
Locomotive crank pins.....	C=380

As the diameter of bearing does not enter into the formula, it follows that, aside from considerations of strength, the correct way to decrease work of friction is to make the diameter small and the length great, but for practical work the strength of materials will limit us to a certain ratio of diameter and length.

Mr. Albert Kingsbury (Non-Member)—The uniformity of the results of the experiments of Tower which have been described, and the low coefficients of friction which he obtained, led to a mathematical investigation by Prof. Osborne Reynolds. His paper entitled, "Theory of Lubrication" (Philosophical Transactions, 1886) was the first, and is still the greatest, theoretical work on this subject. He showed that the data obtained in Tower's experiments could all be calculated approximately, starting with the coefficient of viscosity of the oil as a basis. He also deduced some conclusions that were not brought out by Tower's observations, one being that in one case when the bearing pressure was 100 lbs. per sq. in of projected area the minimum thickness of the oil film was .000375 inch and the difference of the radii of the brass and journal .00077 inch. He also showed that in the experiment in which the maximum oil pressure was 625 lbs. per sq. in., the pressure in the oil must have been below atmospheric pressure for a short arc near the "off" edge of the brass. Besides many other interesting deductions, the paper contains a simple resume' of the results of the theory, with diagrams showing the general behavior of the lubricant in the film. Some of Reynolds' conclusions, for which there was no direct verification

in Tower's work, I found to be borne out in some experiments with an air-lubricated journal, which are described in the Journal of the American Society of Naval Engineers, Vol. IX., No. 2 (1897). Among these conclusions are those relating to the effects of variation of the speed upon the thickness of the oil film, upon the position of the thinest point of the film, and upon the positions of the points of greatest and least pressure in the film. The existence of regions of "negative" pressure was also demonstrated in my experiments, which were made with a complete ring for the bearing shell. I later constructed some bearings for experimental machines in which this negative pressure was utilized to maintain a free oil supply. For example, in a small electric motor with overhung pulley, the belt pull being upward, the oil pressure was below atmospheric pressure at the bottom of the bearing next the pulley, and at the top of the bearing at the other end of the shaft. Connecting these low-pressure points to the oil-reservoirs below the bearings by small tubes, oil flowed up through the tubes freely supplying the bearings, the overflow at the ends of the bearings was returned to the reservoir in the usual way. This device, of course, required good fitting and proper attention on starting. It would not serve for rough work or for bearings subject to much wear, unless they were "primed" each time on starting. The experiment however was entirely successful as such.

Mr. John Ruddman (Non-Member)—Is there any possible way of protecting the roll necks from the scale? Is there any shield made whereby that can be done? Although suet had been used a long time some people wanted to stop using suet and use grease. Grease answered very well and it was cheaper, but the scale would mix in with the grease and ultimately get in to the neck, which did not happen with the suet.

Mr. H. H. Anderson—That has been tried in some cases by grooving the end of the roll and putting a shield on, but it is not very often used. The workmen in changing rolls would

neglect to put the shield back in place, and it was also found to be in the way.

Mr. G. M. Campbell, Mem. Eng. Soc. W. Pa.—There are great differences in the unit pressure allowed on different classes of machines. In one of the largest steam turbine works they limit the pressure on the bearings to 50 lbs. per square inch. That seems extremely low. I would like to know if any one here know what is the general practice with high class steam engines.

Mr. J. L. Klindworth—For main bearings of engines I would allow from 100 to 150 lbs. per square inch pressure. In this connection I might mention the formula of Mr. Edwin Reynolds, which I consider as giving good results for engine bearings.

The max. pressure per sq. in. should not exceed $\frac{C}{\sqrt{V}}$

Where V=velocity of rubbing surface in feet per second.
C=500 for vertical engines and
350-375 for horizontal engines.

Mr. H. H. Anderson—In rolling mill designing they generally take a formula, work it out, then multiply the result by two. They do not regard its looks as long as they obviate the chance of breakage. It seems to be the idea to get as much material as possible within a given space.

Mr. Gerald E. Flanagan, Mem. Eng. Soc. W. Pa.—Mr. Cronemeyer laid some stress on the fact that rolling mill engineers had to use judgment about formulae for determining bearings, and Mr. Klindworth's remarks trend in the same direction. This is not peculiar to rolling mill design. It ought to be evident from the discussion tonight that formulae for any given class of bearings apply only within very narrow limits. Apparently rules for designing bearings for roll necks will not

apply to the engines that drive them. It gets back to the position that with all we can learn on the subject, and all the theorizing we can do on it and all that the professors, eminent for mathematical knowledge and research, can do to help us, that experience is the chief factor in the designing of a bearing. You cannot design bearings from book knowledge. Book knowledge is of great value to each man in his own department, when supplemented by experience, but the designer of bearings in any line of engineering does not need to feel small because he is unable to design them in a line in which he has had no experience.

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SAMUEL DIESCHER.

Vice-Presidents.
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THOS. H. JOHNSON, Chairman.
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STRUCTURAL SECTION.

E. K. Morse, Chairman.
R. A. Cummings, Vice-Chairman. T. J. Wilkerson, Secretary.

Directors.
T. D. Lynch, Francis S. Rice.

PROCEEDINGS OF THE

Engineers Society of Western Pennsylvania.

VOL. XXI JANUARY, 1906 No. 10

THIS SOCIETY DOES NOT HOLD ITSELF RESPONSIBLE FOR THE OPINIONS OF ITS MEMBERS.

The 260th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the lecture room of the Society's House, 410 Penn Avenue, Pittsburgh, Pa., Tuesday, December 19, 1905, at 8:15 P. M., President Samuel Diescher in the chair, with thirty-five members and visitors present. The following gentlemen registered:

MEMBERS:

Bachtel, S. R.,
Barnsley, Geo. T.,
Blum, Louis P.,
Cummings, Robt. A.,
Danforth, G. H.,
Davis, Charles,
Davis, Wm. M.,
Dittmar, Edw. J.,
Finley, Norval H.,
Flanagan, Gerald E.,
Geisey, V. A.,
Kintner, S. M.,
Lynch, T. D.,
McMullin, F. V.,
Miller, R. E.,
Moore, L. C.,
Morse, E. K.,
Rice, Francis S.,
Sikes, Z. H.,
Stevenson, J. D.,
Stucki, A.,
Whitman, Paul S.,
Wilkerson, T. J.,
Winter, F. W.,

VISITORS:

E. F. Carver,
F. W. Lee,
F. F. Lyon,
R. H. Montgomery,
J. O. Holmes.

The minutes of the previous meeting were read and approved.

The report of the Board of Direction was read, recommending for membership six applicants.

On motion the Secretary was instructed to cast the ballot of the Society for their election.

On behalf of the Reception Committee, Mr. Barnsley reported that the Annual Banquet will be held January 26, 1906, at Hotel Schenley. Price of tickets, $5.00.

A paper on "Insulation, Its Principles as Relating to Cold Storage Practice," by J. B. d'Hommergue, was read by Frederick W. Winter, the author being unable to appear before the Society.

The discussion which followed was participated in by Messrs. McConnell, Kintner, Stucki and Diescher.

On motion a vote of thanks was tendered Mr. d'Hommergue for his paper.

On motion the meeting adjourned at 10:00 P. M.

F. V. McMullin,
Secretary.

NEW MEMBERS.

NAME	OCCUPATION AND ADDRESS.	ENDORSED BY
JOHN C. CARR,	Draftsman, Uniontown & Wheeling Short Line, 913 Farmers Bank Bldg., Pittsburgh, Pa. h. 325 Arbella St., Knoxville, Pa.	Craig R. Branson, G. F. Freed, J. M. Armstrong.
R. H. DEMPSEY,	Engineer, Webster Mfg. Co., 307 Forbes Bldg., Pittsburgh, Pa.	W. M. Judd, W. O. Abbott, J. F. Kuntz,
J. R. FORTUNE,	Rep. Murphy Iron Wks. 1216 Empire Building, Pittsburgh, Pa.	Edwin Fitts, F. V. McMullin, Samuel Diescher.
VICTOR A. GIESEY,	Sales Agent, Harbison-Walker Refractories Co., h. Cor. Ella & Walnut Sts., Wilkinsburg, Pa.	James O. Barnett, Wm. O. Amsler, Victor Beutner.
JOHN A. McEWAN,	Ass't. Engineer, Pittsburgh Bridge & Iron Works, 341 6th Ave., Pittsburgh, Pa. h. R. D. No. 1, Carnegie, Pa.	L. W. F. Hildner, Geo. E. Klingelhoffer, Chas. T. Klingelhoffer
W. H. H. MILLER,	Supt. & Mgr., Cochran Coal Co., Salina, Pa. h. Saltsburg, Pa.	Geo. L. Miller, Samuel Diescher, E. J. Taylor.
KARL A. MULLENHOFF,	Draftsman, American Steel & Wire Co., Office of District Engineer, h. 813 Franklin Ave., Wilkinsburg, Pa.	W. H. Baltzell, F. V. McMullin.
WALTER C. ROTT,	Mechanical Eng., with Julian Kennedy, h. 227 Halket St., Pittsburgh, Pa.	Robt. W Grange, Jr., Walter Rachal, S. R. Bachtel.
WALTER H. WHEELER,	Sales Mgr., Pittsburgh District for Browning Engineering Co., Cleveland, 1103 House Building, Pittsburgh, Pa.	A. M. Acklin, W. E. Fohl, M. Greenwood.
EDWARD W. WURTZ,	Mech. Eng., American Window Glass Co., h. 624 S. Lang Ave., Pittsburgh, Pa.	Robert Linton, E. D. Leland, R. W. Bridge.

MONTHLY MEETING OF THE BOARD OF DIRECTION.

The regular monthly meeting of the Board of Direction was held at 410 Penn Avenue, Saturday, December 16, 1905, at 8:15 P. M.

Present: Diescher, Flanagan, Kintner, Lyons, Whited, Barnsley, Knowles and Secretary.

The following resignations were accepted:

Horace S. Clark,	Percy Nicholls,
H. B. Prather,	Harry L. Preston,
Ludwig Hommel,	Marshall Williams.

Treasurer's report:

Building Fund	$ 320.58
Permanent Fund	220.20
Checking Account	769.16
Total	$1,309.94

Secretary's report:

Membership December 16th, 1905...945

Collections Nov. 18th, to Dec. 16, 1905	$ 516.30
Previously reported	8,972.95
Total 1905,	9,469.25
Total Dec. 16, 1904,	6,318.93
Increase, 1905,	3,150.32
Payments to Dec. 16, 1905	7,444.00
Bills were paid aggregating	265.95

On motion the Secretary was instructed to secure estimates on reprinting volumes II, III, and IV of the "Proceedings, and to attempt to purchase enough missing copies of volume XVII to make 25 volumes.

On motion it was decided not to print a new Membership List until July.

On motion the clerk's salary was raised to $50.00 per month.

On motion adjourned at 10:50 P. M.

F. V. McMullin,
Secretary.

CHEMICAL SECTION.

The regular monthly meeting of the section was held at 410 Penn Avenue, Thursday, December 21, 1905, with the Pittsburgh Section of the American Chemical Society.

In the absence of the chairman and Vice-chairman the Secretary called the meeting to order at 8:20 P.M. Twenty-two members and visitors were present.

On motion C. H. Rich was elected chairman *pro tempore*.

The minutes of the last meeting were read and approved.

Through its chairman, Dr. F. C. Phillips, the nominating committee appointed at the November meeting reported the following nominations for officers for 1906:

Chairman, Lawrence L. Arnold.
Vice-Chairman, Jacob A. Mohr.
Secretary, Harrison W. Craver.
Directors, { James M. Camp, Harry E. Walters.

C. M. Johnson read a paper on the "Determination of Carbon in Steel by direct Ignition with Read Lead." This was discussed by Walters, Babbitt and Phillips.

Dr. Phillips asked for methods of opening plugged cylinders of liquid chlorin.

After some discussion of this question the meeting adjourned at 10:10 P. M.

Harrison W. Craver,
Secretary.

MECHANICAL SECTION.

The regular monthly meeting of the Section was held at 410 Penn Avenue, December 5, 1905, at 8:15 P. M., with Chairman H. H. Anderson in the chair and 23 members and visitors present.

The Secretary being absent the reading of the minutes of the previous meeting was dispensed with.

C. E. Watts presented a very able paper on "Economy in Fuel at Bituminous Coal Mines." The discussion which followed was participated in by Watts, Anderson, Albree, Lane, Moore, Lynch, Cole, Campbell and McGrew.

On motion the meeting adjourned at 9:45 P. M.

STRUCTURAL SECTION.

The regular monthly meeting of the Section was held at the Society's House, 410 Penn Avenue, Tuesday, December 26, 1905.

The meeting was called to order by Chairman E. K. Morse, at 8:30 P. M., with twenty-one members and visitors present.

Minutes of the last regular meeting were read and approved.

The report of the Nominating Committee was read by the Secretary:

Chairman, Robt. A. Cummings.
Vice-Chairman, Thos. D. Lynch,
Secretary, G. H. Danforth.
Directors, { Ralph Crooker.
F. M. Bowman,

Willis Whited, member, read a paper on "Urban Bridges."

The following gentlemen joined in the discussion: Affelder, Albree, Danforth and Blum.

On motion, the meeting adjourned at 10:30 P. M.

T. J. Wilkerson,
Secretary, S. S.

*FUEL ECONOMY AT BITUMINOUS COAL MINES IN PENNSYLVANIA.

†C. E. WATTS

Member.

The first move toward replacing hand mining by machine mining methods was made in the year 1858, when Elisha Simpkins, of Allegheny, Pa., was granted a patent on a mechanical device for the under cutting of coal.

At this time the yearly tonnage produced by the mines in the Bituminous Regions of Pennsylvania was dependent almost entirely on man and animal labor, the coal being mined by hand pick work, and hauled by horses or mules.

The system employed by mine operators of the present day is almost universally backed by certain amounts of assistance obtained from a mechanical source developed as the result of experience and necessity, by the energy of philosophical men.

In the year 1876, Mr. Francis M. Lechner, of Columbus, Ohio, was granted a patent on a rotary bar breast machine.

Two years later in 1878 J. W. Harrison was granted a patent on a pick or punching machine which was really the first of its kind to demonstrate the successful application of the mechanical mining machine which was, as time has proven, destined to be of great assistance to the mine operator, both as a means of obtaining a large output from a given area of territory in a limited time, and also cheapening the cost of production when judiciously applied.

Although ambitious men were in 1878 able to demonstrate the practicability of mechanical mining machines it was seventeen years later, or 1895, just following the labor troubles of 1894 with which the coal business of Pennsylvania was so

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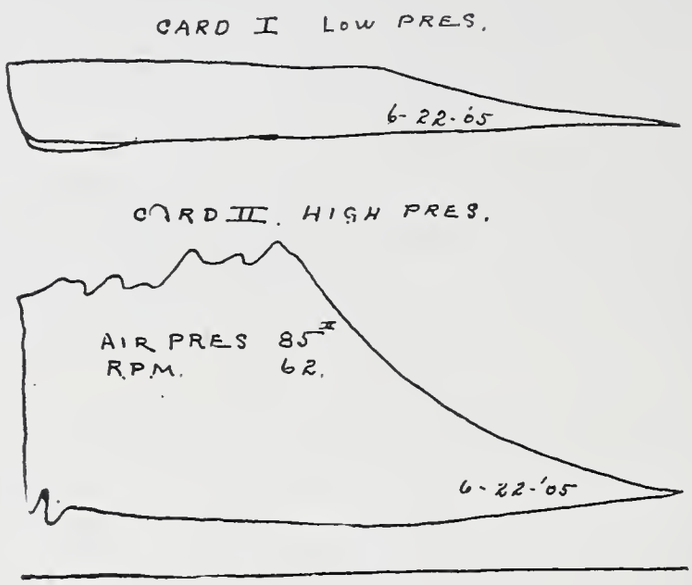
* Meeting of Mechanical Section, December 5, 1905.

† Windber, Somerset County, Pennsylvania.

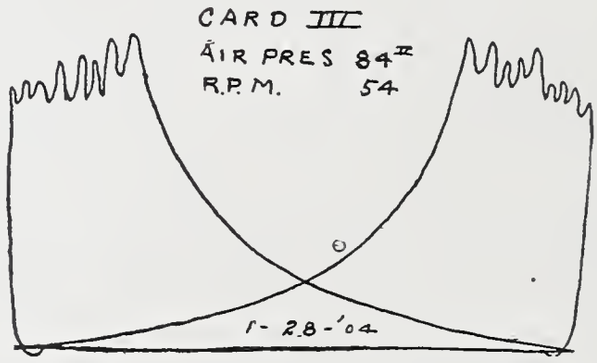
sorely affected, before the mining machine received any substantial consideration from the mine manager.

Previous to this time, the strenuous manner in which the miners opposed the installing of mining machines had its damping effect upon their adoption by coal operators, but in

AIR CYLINDER CARDS.



CARDS I AND II SHOW ACTION OF TWO STAGE COMPRESSION WITH MECHANICALLY MOVED INLET, AND POPPET DISCHARGE VALVES



CARD III SHOWS ACTION OF SINGLE STAGE COMPRESSION WITH PISTON INLET, AND POPPET DISCHARGE VALVES.

1895 and 1896 the mining machine had its opportunity, proved its advantages, overcame successfully all opposition and has been from that time steadily replacing the hand method of mining, its advantages being recognized and admitted by both operator and miner.

By referring to table II., the progress of the mining machine may be comprehensively studied. Along with the development and adoption of the mining machine, also has progressed and developed the adoption of mechanical coal haulage, ventilation, pumping, heating, lighting, repairing, etc., until at the present time it is conceded by every coal operator that he can with advantage use some form of mechanical energy in any and all conditions of mining to a greater or less extent in the production of coal.

To substantiate this statement I will refer to Table I., columns 7-8-10-11-12-13, where the steady increase of machinery applied to mining and hauling coal during the years 1900 to 1903 inclusive is shown.

It is then within the last ten years that mechanics have so strongly invaded the field of coal mining, during which time the yearly total coal production of the state has been somewhat more than doubled, and machinery is cutting practically 38 per cent. of the present output.

Since this advancement has been made in the last ten years what may be reasonably expected to develop during the next few years is a matter, which by careful engineering, based upon experience already at hand, may be of more financial benefit to the operator than has heretofore been realized.

The principal motive for machinery installation until very recently, has had but one object in view: That of installing the machinery and getting the work out of it, which it is expected to perform, without regard to economy.

It must be conceded that this is a very natural channel for the coal operator to follow, since in the first place, there may be refuse or unsalable coal in quantities sufficient to operate, in whole or in part, the machinery which he sees fit to install.

In the second place, the annoyance from labor troubles, difficulty of obtaining reliable help with sufficient knowledge and experience to care for other than the most simple machinery, and the apparent excessive first cost of the better class of machinery has its virtues, and it is sterling judgment when

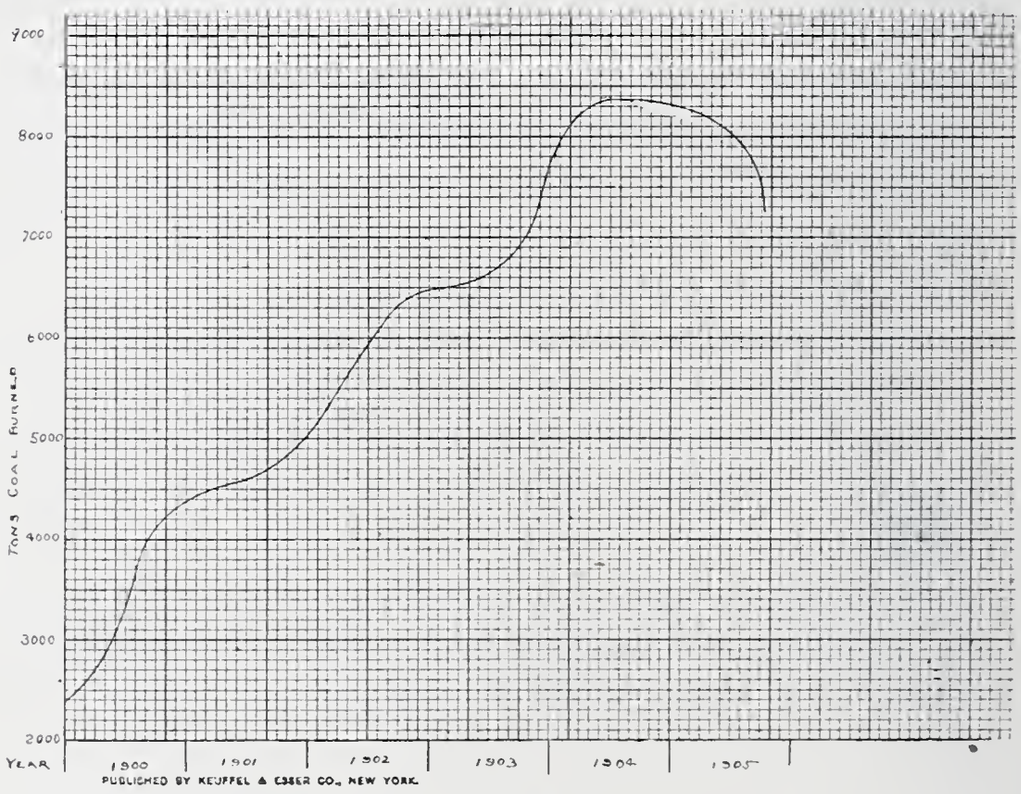
one clings to the old and tried methods, until he is convinced that some other method is an improvement over them.

Thus it has come to pass that much of the mechanical equipment used, and many methods of applying the same, in production of coal today, are far from reasonable economy in coal consumption and in many cases handicapping the economical production by interruptions of service for minor repairs, and also by inadequate service altogether.

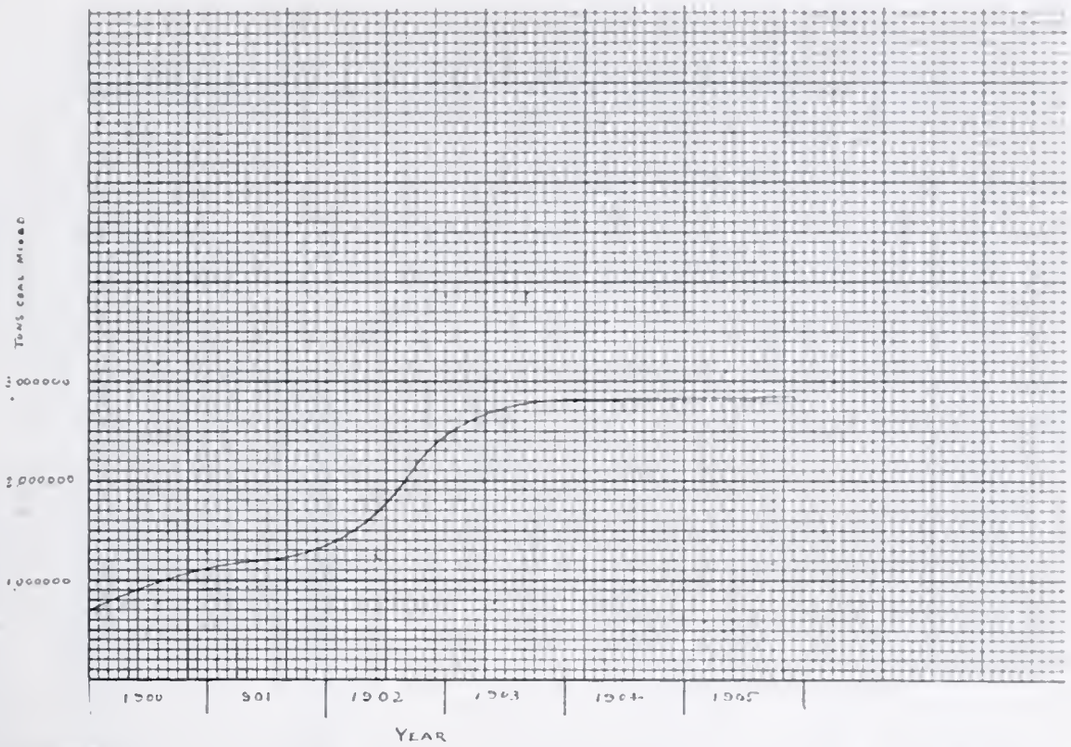
The mechanically equipped mine of the present day embraces, first, a boiler plant at which steam energy is generated to be transformed into many different forms of energy and used for many different purposes.

The source of mine lighting and ventilation, cutting, hauling or hoisting coal, pumping the water from or about the mines, lighting and heating the buildings in connection with the mines, operating the mechanism at the tipple for dumping and handling the loaded cars, giving to the blacksmith forges and to the repair shops the air, steam, or electricity necessary for their needs, are a few of the many uses to which the steam boiler energy is given.

In column 22 of Table I., it will be seen that the per cent.



CURVE 1. INCREASE IN CONSUMPTION OF COAL AT MINE.



CURVE 2. INCREASE IN PRODUCTION OF COAL AT MINE.

of coal consumed at the mines in Pennsylvania increases from year to year as the amount of mechanically produced coal increases.

If 37.5 per cent. of the total coal production is mechanically mined, and the amount of pumping, ventilating, and hauling mechanically performed today, requires a consumption of 2.28 per cent. of total production, what will be the per cent. consumed when the mechanical methods are as fully developed along the lines now adopted as it is possible for them to be and what does it mean to the operator?

The data which I have at hand on this matter is shown in Table III., giving coal mined, burned, and per cent. of total production consumed, also by plotted curves I and II, showing graphically the increase in production and consumption of coal at the Eureka mines of the Berwind-White Coal Mining Company now in operation at Windber, Pa., with which work I have been connected from its beginning.

At these mines all the work connected with the coal production is done entirely by mechanical methods, obtaining a coal production of practically 3,000,000 tons per year. There are no mules used, and the amount of hand pick work is so small as to be negligible.

TABLE I. BITUMINOUS COAL FIELDS OF PENNSYLVANIA.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Year	Number of mines producing coal	Cylinder boilers used	Tubular boilers used	Steam locomotives used	Air locomotives used	Electric locomotives used	Stationary steam engines used	Pumps used	Air operated mining machines used	Elect. operated mining machines used	Dynamos used	Air compressors used	Total number of men employed
1891													74,135
1896													83,804
1900	887	561	1,062	119	17	174	1,124	575	980	312	196	195	108,837
1901	960	458	1,435	141	32	212	1,354	322	1,011	460	241	225	117,602
1902	1,061	492	1,689	130	16	323	1,615	884	1,932	880	306	337	134,986
1903	1,215	431	2,039	162	23	435	1,954	1,075	2,339	1,045	391	446	151,745

TABLE I. BITUMINOUS COAL FIELDS OF PENNSYLVANIA—CONT'D.

15	16	17	18	19	20	21	22
Total number of mules used	Total number of tons of coal produced by air operated mining machines	Total number of tons of coal produced by electric operated mining machines	Total number of tons of coal produced by hand pick	Total number of tons of coal burned by boilers at the mines	Total tonnage mined	Per cent of total amount of coal mined by air and electric machinery combined	Per cent of total amount of coal mined which is consumed at the mines
					42,787,644	1.01	
					49,557,453	12.3	
9,833	19,064,853	7,802,200	52,975,273	1,327,256	79,842,326	33.6	1.67
10,108	19,962,256	8,159,534	52,792,446	1,435,661	80,914,236	34.6	1.77
11,833	17,945,014	18,410,593	62,590,596	1,992,499	98,946,203	36.4	2.01
12,899	20,106,840	18,444,186	65,162,956	2,351,622	103,713,982	37.5	2.28

There are nine openings of the drift type from which coal is taken to the separate tipples. At each opening is located an independent power plant consisting of boilers, electric generators and engines, and air compressors.

These power plants furnish 500 volt direct current used by mining locomotives for hauling coal, compressed air at 75 pounds pressure for puncher type mining machines, rock drills used in cutting coal, taking down roof and taking up bottom, also compressed air used for pumping the water out of the mines where it is necessary.

This system contains 7000 rated boiler horsepower, 2850 K. W. of 500 volt D. C. generators with engines to operate same.

TABLE II.

BITUMINOUS COAL FIELDS OF PENNA.

Year	Number of mines using machines for cutting coal.	Number of machines used, Electric or Air operated.	Total Tonnage.	Tons mined by machines, Electric or Air operated.	Per cent. of total product mined by machines.
1891	7	72	42,787,644	431,440	1.01
1896	41	454	49,557,453	6,092,644	12.3
1900	73	1,786	79,842,326	26,867,053	33.6
1903	390	3,384	103,713,982	38,551,026	37.5

Compressors sufficient to compress 36000 cubic feet of free air per minute to 75 pounds gage pressure.

The above energy generating system furnishes energy to 56 thirteen ton electric locomotives, 340 puncher type air operated mining machines, 24 air operated rock drills, 120 air operated mine pumps delivering an aggregate of about 7600 gallons of water per minute, 9 Capell steel fans of sizes ranging from 140,000 to 240,000 feet capacity (none of these fans are required to produce more than one-half of their capacity at

the present time) besides furnishing numerous repair shops with electricity and compressed air, and heating about 90 buildings connected with the mines. It is seen by Table III., that with the coal production constant for the years 1903-4 that the coal consumption increased from 2.83 per cent. to 3.37 per cent. This is due principally to the progression of the mine, the energy having to be transmitted further and the ton mileage increasing accordingly.

TABLE III.

BITUMINOUS COAL FIELD AT WINDBER, SOMERSET COUNTY, PENNA.

Year.	Total coal mined, 2000 lb. tons.	Total coal consumed, 2000 lb. tons,	Per cent. consumed.
1900	2,055,115	43,480	2.11
1901	2,206,506	55,386	2.50
1902	2,744,216	74,115	2.70
1903	2,913,135	82,642	2.83
1904	2,911,830	98,427	3.37
1905	2,910,000	91,819	3.15
Total	15,740,802	445,869	2.83

NOTE—The last two months of the year 1905 have been estimated upon the basis of performance during the preceeding months of July and October, 1905.

During the development of these mines machinery was installed which was known to be reliable, but with the idea of economy of energy production on the obscure horizon. In 1903-4, after the desired coal production had been obtained it was found that the amount of generated energy would soon be insufficient to maintain the production as the mine workings

drew further and further away from the source of power, so provisions were adopted to overcome this and at the same time to overcome the condition in as economical a manner as experience had demonstrated to be practicable. To do this the concentration of large size electric units, operated by compound condensing engines, was the first step. Second, replacing the straight line single stage air compressors by compound steam, single stage air compressors, and where convenient, compound condensing steam, double stage air compressors were to be installed. Third, eliminating as far as possible pumping water by compressed air. Along these lines a substantial saving in coal consumption and labor of attendance required to operate the machinery will be made.

To substantiate this refer to curve I, where it is seen that during the year 1905 the coal consumption has been reduced practically 1000 tons per month, and I may add that the air pressure at three of the mines has at the same time been greatly improved.

This saving was realized by replacing five 1,500 ft. capacity straight line air compressors by three compound steam, single stage, Corliss compressors of 3,000 cu. ft. capacity each and by discharging 2000 gallons of water per minute from the mines by a duplex compound condensing steam pump, which work had previously been done by compressed air.

The benefits to be derived from the concentration of large electric units and the compound condensing two stage air compressors are yet to be realized.

The constant energy supply required at coal mines is recognized in ventilating, pumping, lighting and heating. The regularly fluctuating energy required is recognized in cutting, drilling and hauling. Sometimes these last three energy consumers do not fluctuate much, but this depends upon the method employed in the working of the mine; that is, whether the plant is wholly or partly closed down at night. In many mines, the night shift work requires about as much energy for cutting, drilling, hauling, lighting and heating as the day shift. In ventilating, the fact is perhaps not considered that for every ton of coal produced from 7.5 to 12 tons of ventilating air is

TABLE IV. SHOWS COMPARATIVE COST OF INSTALLING AND MAINTAINING STEAM ENGINE PLANTS OF DIFFERENT TYPES

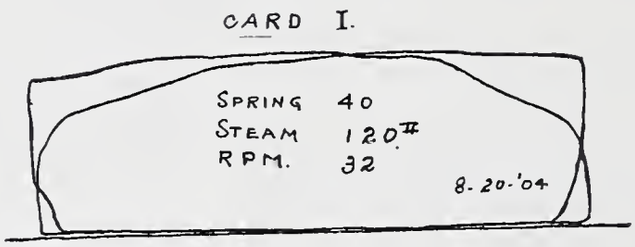
1	2	3	4	5	6	7	8	9	10	11	12	13	14
TYPE OF ENGINE.	Steam pressure in pounds by gage.	Pounds of feed water required per I. H. P. per hour.	Commercial H. P. of boilers required on basis of 34.5 lbs. of water evaporated at 70 lbs. gage pressure from and at 212 F. to furnish 1-I. H. P. in engine.	Cost per I. H. P. of engines erected and connected ready to operate and covered by brick buildings.	Cost per I. H. P. of boilers erected and connected ready to operate complete with stacks, feed water heating and pumping equipment, and covered by brick buildings on basis of $28.45 per commercial H. P.	Total of two preceding columns.	Pounds of water evaporated in boilers per pound of dry coal.	Pounds of coal consumed per I. H. P. per hour by engine.	2000 lb. tons of dry coal required per I. H. P. year, on basis of 24 hours per day for 308 days per year.	Cost per I. H. P. per year for maintenance and operation, not including coal, on basis of 24 hours per day for 308 days per year	Interest on investment, taxes, depreciation, @ 8% of amounts in column seven.	Total cost per I. H. P. per year of all operating, interest, and depreciation expenses including coal at $1.20 per 2000 pound ton.	Relative per cent of efficiency in maintainance and operation complete, on basis of 24 hours per day for 308 days per year.
1 Simple high speed non-condensing	90	32	.870	$20.10	$26.50	$46.60	9.0	3.55	13.15	$11.48	$3.73	$31 65	54.
2 Simple high speed condensing	100	26	.754	$22.50	$21.40	$43.90	9.0	2.88	10.65	$10.41	$3.51	$27.22	62.8
3 Compound high speed non-condensing.....	120	22	.640	$27.40	$18.20	$45.60	9.5	2.32	8.55	$ 9.52	$3.65	$23.85	71.6
4 Compound high speed condensing.....	150	16	.464	$29.50	$15.55	$45.05	10.5	1.52	5.56	$ 8.64	$3.60	$19.19	89.2
5 Triple expansion high speed condensing.....	200	12	.348	$36.30	$12.90	$49.20	10.5	1.15	4.24	$ 7.84	$3.94	$17.11	100.0

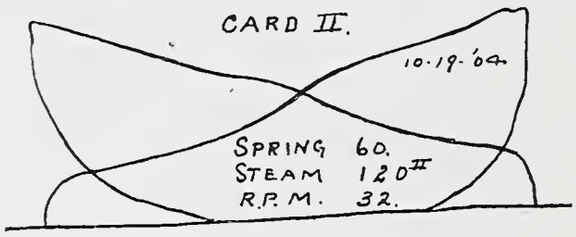
delivered into the mine, and this perhaps against an unnecessary water gage.

It therefore should be seen to that the fan be of an efficient type, also that the air supply to the fan be very ample and that the air passages be of sufficient area to obviate great depression of water gage if suction fan, or an excessive positive water gage if a blowing fan.

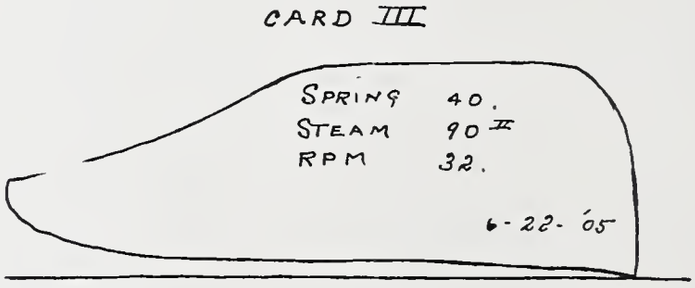
The tendency of recent fan practice is for small quick moving fans, this in turn opens the way for the application of multiple expansion engines for driving purposes.

The universal practice is to attach a single cylinder engine, side crank connection, steam cutting off anywhere from 5-8 to 7-8 stroke, to these high speed fans and allow them to saw

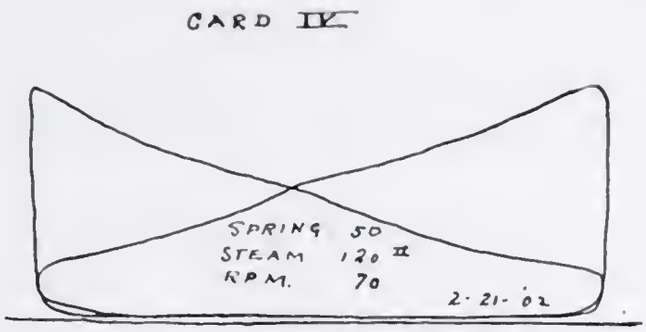




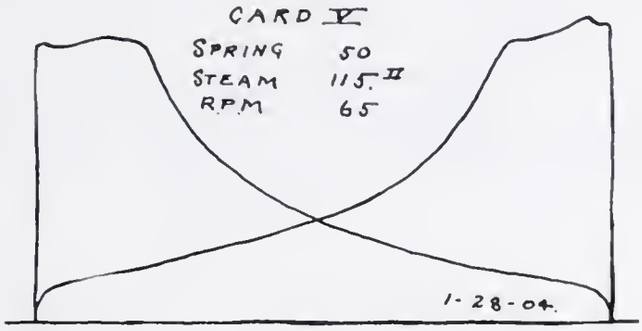
CARD I TAKEN FROM STEAM END OF 24" x 36" DUPLEX AIR COMPRESSOR.
CARD II TAKEN FROM SAME CYLINDER AS CARD I. AFTER ALTERATING OUTSIDE AND INSIDE LAP AND LEAD OF VALVE.



CARD III TAKEN FROM STEAM END OF 24" x 30" STRAIGHT LINE AIR COMPRESSOR.
RIDING CUT OFF MEYERS VALVE WITH ECCENTRIC SHEEVE KEYED ON.



CARD IV TAKEN FROM STEAM END OF 24" X 30" STRAIGHT LINE AIR COMPRESSOR. MEYERS RIDING CUT OFF VALVE WITH MOVABLE ECCENTRIC SHEEVES. WATER CONSUMPTION 42 LBS.



CARD V TAKEN FROM STEAM CYLINDER OF 20¼" X 36" DUPLEX CORLISS ENGINE DRIVING AIR COMPRESSOR. WATER CONSUMPTION 24.8 LBS.

away day and night for years, with a steam consumption not less than 30 pounds and in many cases as high as 50 pounds per horse power per hour.

There is no load which more admirably fits a multiple expansion engine than the load of a fan because of its constancy, and there are few fans now driven by single cylinder engines which cannot be driven with advantage by a compounded engine with a saving in coal of from 12 to 20 per cent.

Again we find a most serious waste of energy in the transmission and use of compressed air. The losses in transmission are usually due to too small pipes, leakage in the line due to inadequate weight or kind of fittings used and by poor workmanship on the lines. It is frequently the case that 30, 40 and even 60 per cent. of the compressed air generated is lost through one or more of these causes in the transmission alone.

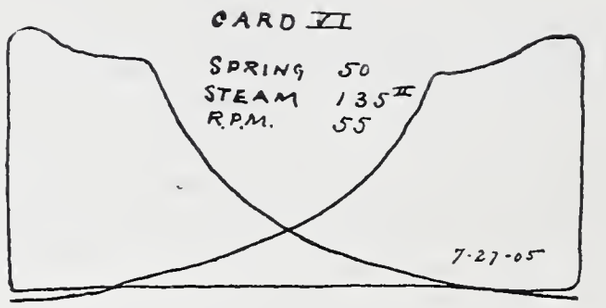
Pumping water by compressed air is one of the most common practices where air is carried into the mines for coal cutting purposes.

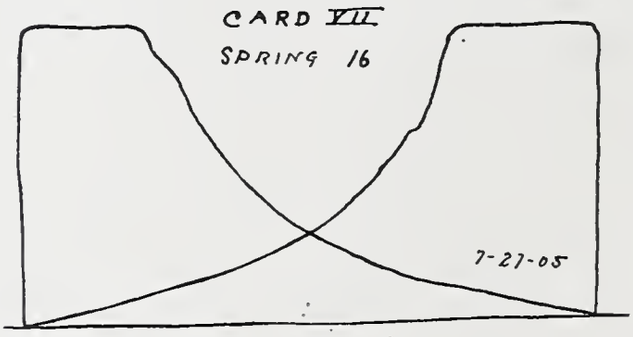
Generally we find these pumps using the air to be an ordinary design of stock steam pump with the ratio of steam to water cylinder anything but the most advantageous for this kind of work.

Common practice shows that it requires from five to eight boiler horsepower to yield one net horsepower in water pumped.

It is therefore conceded that compressed air is an expensive luxury at best as used today about coal mines, especially when the most economical methods are not used in its production.

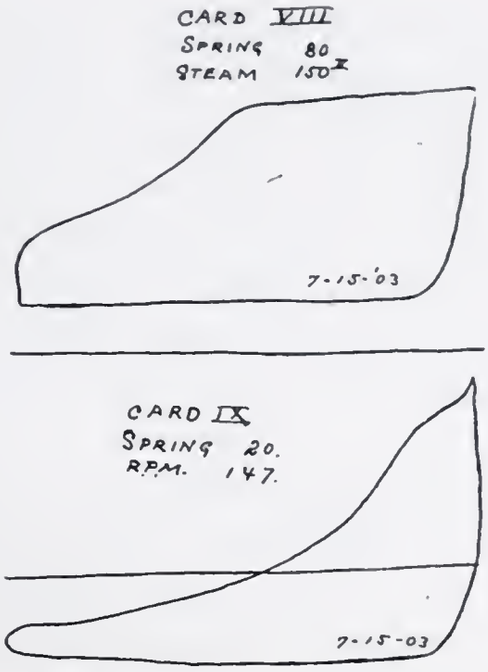
An inspection of indicator cards I to IX inclusive shows the steam distribution obtained by engine valves of different types.





S VI AND VII TAKEN FROM HIGH AND LOW PRESSURE STEAM
YLINDERS RESPECTIVELY OF 23" AND 36" DIAM. X 36" STROKE
ROSS COMPOUND ENGINE DRIVING AIR COMPRESSING CYLINDERS
WATER CONSUMPTION 22.4 LBS.

Also Table IV, showing the comparative cost of steam power developed in engines of different types should be convincing testimony that it is advisable to court fuel economy even at Bituminous coal mines.



CARDS VIII AND IX TAKEN FROM HIGH SPEED FOUR VALVE AUTOMATIC ENGINE 15" AND 40½" DIAM. X 27" STROKE. COMPOUND CONDENSING AND DIRECT CONNECTED TO GENERATOR.
WATER CONSUMPTION 13.55 LBS.

DISCUSSION.

H. H. Anderson, Member—Is the expense of pumping water by air due to leakage in the pipes, or the distance the air is carried before using, or to the pump that is used?

C. E. Watts—It may be due to a combination of those points. It is very difficult to keep an air line tight, even if it is tight when first laid, as there are many sub-branches all terminating in the rooms where the miners have access to the valves on the end of the pipe, and they frequently make the valves leak in order to clear the smoke out. Most valves after being used several weeks are ready to leak any way. I have seen all the machines shut off of lines that were supposed to be tight, yet the compressors would run a surprising number of revolutions to keep up the pressure.

H. H. Anderson—I would think that the use of air for pumping could be replaced by electricity in non-gaseous mines. It would be impossible to carry anything but electricity far enough from a central powerhouse to run the pumps.

W. M. Judd, Member—Could not more economy be secured by applying electricity to all purposes and not have the double system of power installed in the mine?

C. E. Watts—In many instances electricity could be used to advantage where compressed air is used now, as pumping or coal cutting. It cannot be laid down as a rule, however, that electricity can be used wherever air is used. There are many places where it would be impossible to use electricity but where it is possible to use air. Low coal, coal that is full of sulphur streaks, clay spots and faults, would give you more trouble with electric coal cutters than with a compressed air puncher type machine. I think a greater use could be made of electricity in mines than is being done to-day. At a place where you accumulate a considerable body of water it is practicable to use an electric pump. It would be rather unsatisfactory though to put an electric pump where you pump possibly half a day, and then have to move the pump or shut it down. Under such conditions compressed air will be better than electricity.

C. B. Albree, Member—Do you attempt to use air in ordinary piston pumps?

C. E. Watts—We are not using the air lift at present, though it is practicable to do so. The mines being drift mines, and coal lying fairly level, there is no great head, so that while we are using the piston pump it does not amount to much as a displacement pump, because of a faulty ratio of cylinders.

C. B. Albree—We have had experience in using cylinders of 10—18 inches diameter, and of observing the leakage past the piston rings. With any type of iron packing rings the leakage was very great, so that ordinarily, with the piston stationary, the air leaking past it and out the exhaust would

blow out a candle. That can be overcome by using ordinary hydraulic hemp packing in place of the metal rings, and will result in a saving of at least 25% in air.

C. E. WATTS—When the expansion of air in the cylinder is great and the work is heavy, the pump sometimes freezes, a thin coating of ice forms on the valve seat which lifts the valve off the seat and allows the pump to blow twice as much air through it as would ordinarily be used. With a hundred or more pumps in operation that condition exists more or less all the time.

A. A. LANE, Member—What part does the use of compressed air play in the ventilation of a mine. Is it of practical benefit to the rooms where shots are fired or cutting is being done?

C. E. WATTS—It is used as a temporary relief when the ventilation from the fan is insufficient. But ventilating by compressed air is poor policy, as there cannot be much air added to the general ventilation by what comes through an inch and a quarter pipe under 60 pounds pressure for a couple of minutes at a time.

L. C. MOORE, Member—Do they use duplex pumps in all cases, or do they use single cylinders for air?

C. E. WATTS—The majority of the pumps are single cylinder. Where we can collect sufficient water to make steady work for a fair sized pump we use a duplex pump. But as I stated in the paper we are trying to do away with compressed air pumps. If a sufficient quantity of water can be collected to warrant putting in a large pump, we set a boiler on the outside, run the steam line down a shaft, or down a well drilled for the purpose, and place large units to run by steam.

L. C. MOORE—What is the comparative efficiency of single cylinder and duplex pumps run by air?

C. E. WATTS—For the ordinary stock pump I do not think there is much difference. There are pumps designed for using compressed air which are claimed to be more efficient than ordinary stock pumps designed for steam.

T. D. Lynch, Member—In modern manufacturing, of all kinds, where they are trying to get their unit of operation of the different machines as cheaply as possible, they find that the electric motor is the most economical. I should think that a mine would be an ideal place to use an alternating current motor such as is applicable to rotary pumps.

C. E. Watts—There would be no serious objection to using an alternating current motor where a steam pump could be used. In fact it is done in many places. We have been a little timid about trying the rotary pump. I think an alternating current or even a direct current motor would work all right attached to a rotary pump. The rotary pump would have the advantage since there are fewer working parts to be affected by the acids in the water. Sometimes the sulphur water is so strong that it will eat out a six inch wrought iron pipe in two weeks. The action of the same water on cast iron is not so rapid, nevertheless cast iron water cylinders, bronze seats, valve stems, plungers and rods deteriorate very rapidly.

H. E. Cole, Non-Member—The rotary pump is very different in principle, operation and construction from the centrifugal pump. It is usually built with two cams which mesh, and which also fit in the case as near water tight as is consistent with smooth operation, consequently the presence of sulphurous or gritty waters will wear the working parts very rapidly and reduce the efficiency. The centrifugal pump having no valves, and so constructed that it will allow comparatively large solids to pass, the effects of wear, or an appreciable reduction in efficiency, will not result for a considerable length of time. Consequently I should say that the rotary pump would be very unsatisfactory, and would not have one fifth of the life of a centrifugal pump under the same conditions in coal mines.

H. H. Anderson—About three years ago we installed a rotary pump operated by a motor and it has been running ever since. The first cost is much less than the plunger pump, and it may be more economical to put in a second

rotary pump than to buy a more costly pump in the first place and keep it in repair. They certainly deteriorate very rapidly with sulphur water.

G. M. CAMPBELL, Member—What has been Mr. Watt's experience in preventing corrosion of the delivery pipes from the mine pumps?

C. E. WATTS—All pipes used under ground we have asphalted inside and out, which materially adds to its life. For the discharge of mine water we use either a cast iron pipe, or a wood pipe, except for short distances as from one level to another, where it would be only for a day or a week and the pipe would be small. In such a case we use a wrought iron pipe and replace it when it is eaten out. Asphalting a pipe is certainly a paying investment around a coal mine. Oftentimes the pipe will be piled up, perhaps 1,000 or more feet of it, bought to take advantage of the market conditions and stored to be used later. Wrought iron pipe that is not asphalted, lying outside the mines for a year or more, is greatly affected, and oftentimes when it is stacked up inside the mines to protect it from the weather it will deteriorate much faster even than outside.

G. M. CAMPBELL—Are the delivery pipes of the pump asphalted?

C. E. WATTS—We use wood and cast iron for delivery pipes.

EDWARD MCGREW, Member—I have seen large delivery pipes coated on the inside with cement which is very efficient in resisting the action of mine water. At one of the shafts of the Frick Coke Co., a 24-inch cast iron column pipe had been in use for twelve years when I saw it and they had had no trouble with it, excepting at the bottom where the water made a sharp turn. There the cement had worn away and the elbow had to be replaced. It is the practice now, with the plunger type of pump, to coat the chamber with cement, using the best Portland cement, and to use wood lining in the pumps.

H. H. Anderson—There is a good deal of sulphur in those cements, would that affect it any?

Edward McGrew—It does not seem to affect the iron, but rather to preserve the iron from the action of the acids in the water. It has become common now to use bore holes to pump through. A hole is drilled and an ordinary wrought iron casing put in and is poured around with cement. After the casing is eaten out by the action of the water, the cement lining protects the hole indefinitely.

C. B. Albree, Member—That same principle is applied to bridges over railroads, coating the entire under portion of the iron work with cement. At Fall River, Mass., where a lot of track improvement is in progress to abolish grade crossings, every overhead bridge had a wire netting attached beneath it coated with concrete of 1—1½ inch thickness. I asked the engineer in charge as to its action as a preservative, as bridges under which locomotives are discharging sulphur and steam are eaten away in very short time, I suppose it is a very similar action to the coal mine water, and he told me that their experience had been that bridges coated in that way would last almost indefinitely.

Edward McGrew—What size power house and what size units were used at the mine described in the paper?

C. E. Watts—Each plant has about 1,000 horse power of boilers in units of 250.

L. C. Moore—I understood that this plant was entirely equipped with electric locomotives. That is due, no doubt, to the very easy grades that you have throughout the mines' gangways, or wherever the tracks go. I have known of that mine ever since it was first opened, and have often wondered whether the Company really considered that in the long run there was any saving in that plant as against wire rope haulage. There is nobody better qualified to decide that question as they have different investments throughout the country, and certainly they could tell whether they thought that plant was producing coal at the tipple more economically than, for instance, their plant at Horatio, Pa.

C. E. WATTS.—I think the plant at Horatio is shipping about one-eighth of the coal we are shipping out of Windber. I have considerable data as to the merits of the two systems of power, but I do not have it with me. I am convinced that a long grade of 3% or more against the loads, say for a distance of 3,000 to 5,000 feet, would be more economically handled by rope haulage than by independent locomotives.

C. B. ALBREE—How do you get coal from the entries to the main gangway where you do not use mules?

C. E. WATTS—There are side headings off of which the rooms are turned, the miners load the cars and push them to the room necks and the locomotives go into the side heading, reaching in with a chain when necessary, and get the first half dozen cars, then they use the half dozen cars as a chain and keep backing up the heading collecting their trips. There is more power used and more wear and tear on the motors in performing that side heading work than there is on the main haul after they get on the main line. The main heading part of the haulage is not very detrimental to the motor, but the backing and hauling and stopping and starting under heavy loads is very injurious

EDWARD MCGREW—Has Mr. Watts any comparative figures on the power required by chain machines and punchers?

C. E. WATTS—No. We tried the electric chain machine in the Windber district when we first started and found difficulty in making it work successfully. The cut from the electric machine was so narrow that the coal would not tumble out. With the puncher machine you can cut up from the bottom eight inches, or a foot if necessary, and when the blast is put in over the top of the coal the lump falls out. We ordinarily undercut the coal 5—5½ feet which is deeper than can be done by hand. A good coal cutter in a three foot seam of coal can cut about 100 feet, or from 80 to 125 tons in a day.

*COUNTY ROAD CONSTRUCTION.

A TOPICAL DISCUSSION.

Fred. W. Patterson, Member—If affords me extreme pleasure to have the honor of saying a few words to the brethren of my profession in this portion of the state, who, more than any other class, possess an intimate acquaintance with those peculiar geographical features of Western Pennsylvania which tend to take "road building" in Allegheny County out of the category of generalities and place it in a class by itself. So much of the adverse comment upon grades and cost of construction that has appeared in our newspapers in recent years, is but an echo of statements made by those outside the state and totally unfamiliar with the difficulties which we continually encounter, and which our varied experiences have taught us the best methods of combating and overcoming.

During the period of ten years which has elapsed since the passage of the "Good Roads Act of 1895," it has been my privilege to direct those improvements which have brought hitherto inaccessible districts into closer touch with our city, thus increasing land values and materially assisting in augmenting the public wealth.

Prior to this time the construction and maintenance of the roads of Allegheny County was in the hands, mainly, of improperly-qualified individuals, annually elected for supervisorship by rotation, or in all likelihood, for political reasons, with the to-be-looked-for result that at certain seasons of the year the roads were absolutely impassable.

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During my administration something over 200 miles of road have been improved. In some instances by cutting down hills from as high as 18 per cent. to less than 7 per cent.; in other cases by elevating such roads far above the levels

* Meeting of Structural Section, November 28, 1905.

of the runs or creeks with which they ran parallel, as during seasons of flood it was impossible to distinguish the road from the creek with any degree of certainty. All this has been changed and the roads which heretofore were sometimes impassable, are now open at all seasons. It is such items as is implied by the foregoing; viz., the building of bridges, the construction of stone walls and culverts, the enormous masses of material that were handled to secure such lasting results as is manifested by such improvements, that renders invidious a comparison of cost with those localities where such engineering necessities are an unknown quantity. I will cite but one instance in evidence as to the exceptional cost of road improvement here compared with such work outside this county; in building a road on the Allegheny City side of the river, in a distance of one and a half miles it became necessary to construct seven bridges across the stream and many hundred cubic yards of heavy masonry walls.

Up to the end of the year 1903 the petitions for road improvement were met by rotation, choosing, of course, such localities as had previously not been benefitted. The demand, however, from taxpayers who owned autos for connecting links between the main lines of travel, became so incessant that it was almost imperative to improve these connecting links. In most instances they were short ones, so that a continuous tour or circuit might be made in a given locality.

Let me remark, however, that in no instance is one class benefitted to the exclusion of another. Wherever a road is improved it benefits primarily the producer, the agriculturist, who by means of such improvements is enabled to reach the markets quicker. It likewise benefits the consumer, for he thus procures fresher products and at a lessened figure by reason of closer competition. It benefits also the citizen at large, for it enhances the valuation of all lands in proximity to the improved roads and thus proves an unmixed blessing.

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The methods used in constructing a road are as follows: After surveys and levels have been made with the view of eliminating heavy grades and avoiding abrupt turns, calculations of the necessary cuts and fills follow, and arrangements are made for the proper and effective drainage of the road bed. A trench is made about 16 inches deep and the full width of the road proper. Native stone is then placed on end in the manner prescribed by Telford and the tops are napped off and used as wedges to tighten up the layers. A 15 ton roller is run over to compact and level somewhat this layer of stone. On this is placed the ligonier to a depth of 5 to 6 inches and the steam roller is again used. Finally a layer of screenings is placed on the coarser stone and after copious watering the roller is again brought into requisition, rolling from the outer edge to the center. This gives the requisite crown to the road, so essential for preventing an accumulation of water, the most destructive element in the wear of good roads.

Willis Whited, Member—There is quite a variety of good road material in this county. The blue stone that is found in great abundance in the hills makes excellent foundation and the ligonier stone makes good top dressing, it is very hard and durable and stands the weather.

One of the most serious difficulties an engineer has to encounter in road making in this region is the Allegheny County clay. It is the most treacherous material that I ever dealt with. I know of a retaining wall that was built about 11 feet high and 13 feet thick. It went down to a deep foundation and there was sufficient depth of earth in front to prevent it turning over, and as near as I could judge the concrete it was built of was pretty good, yet the hill slipped and sheared off the wall. The clay is not peculiar to Pittsburg, but it is found very largely in this vicinity. If I were to build a retaining wall where the hill cannot be effectively drained, I should figure the wall to carry a head of water pressure corresponding to the height of the earth embankment. I have seen slides that came to the surface at

a natural slope of about 13°. Anyone building a retaining wall in this district must beware. The hill may be so hard that you have to blast it, yet on exposure to the air for a few days it becomes mud. If this clay can be drained effectively and mixed with broken stone so as to increase the angle of repose, then you can handle it the same as other kinds of earth.

Wm. Martin, Member—The subject of the betterment of our highways is spreading over the entire country, and their value is universally understood. The common highways are feeders in a large degree to the railways, and when they are built of a character to insure their reliability at all times, would so equalize the traffic that congestion would be avoided.

It is a notable fact that but little improvement has been made in road construction since Macadam and Telford introduced their methods nearly one hundred years ago, about the same character of work is done, the only notable difference being the tools used, as the steam road roller and stone crushing machinery.

With the best broken-stone roads the surface is never so hard but that it will yield to, and be broken up by, the horses' feet. This loosened material is pulverized by the wheels of vehicles, which in dry weather produces dust, and in wet weather mud, and when the traffic is heavy the cost of maintenance is excessive.

There has recently been brought to public attention a new departure in road construction, viz., a steel track road. A type of this is built at Etna on the Allegheny and Butler Plank Road, Allegheny County, Pa., and also in the suburbs of the city of Louisville, Ky. It is a Tee rail supported on cast iron standards and base-plates, these latter are spaced eight feet apart and supported on a bed of broken stone ballast. The space between the rails may be built the same as the ordinary broken stone road. This rail has a flat top, six and a half inches in width, and a low flange one quarter inch in height; experience has proven that this height of

flange is insufficient and should be made a height at least three quarters of an inch. The track on the Allegheny & Butler Plank Road begins at Etna extending towards Butler and is a single track one mile in length, at the Etna end of the road it is built double track for a length of 500 feet. It has been built and in use about five months, has been under a very heavy traffic and is at this time in excellent condition. This type of road has a fascination for the horses, they will invariably get onto the track of their own volition, apparently knowing when they strike a good thing. As we have steel running on steel the frictional resistance is very small, enabling much larger loads to be hauled with the same power.

Another method of constructing steel track road is by building the rail in a monolithic beam of concrete, thus eliminating the cast iron standards and base-plates and establishing a firm foundation. The space between the rails can be built of broken stone as previously stated.

An enduring road of the steel rail type built with the monolithic beam of concrete, and the space between the rails also of concrete, would be the ideal road and I believe the day is not far distant when it may be realized. The cost of such a road, about $5,000 a mile, is not prohibitive, it being very little if any in excess of the present cost of road making, especially when the cost of maintenance is taken into consideration, as cost of maintenance of a concrete steel track road would be almost nil. For a period of five years the cost of maintenance of the ordinary stone road would about equal the cost of the concrete steel track road, which latter at the end of the period named would be almost as good as when first built. It is confidently believed that the concrete steel track road will save the country many millions of dollars annually.

J. S. Campbell, Non-Member—If roads were made about four feet wider in the improved part the road would be more enduring, as the width they are built now does not permit

passage of teams on the improved part, and driving out over the edge wears out the improvement rapidly.

W. M. Judd, Member—The width of road would depend very largely on the character of the traffic. With a country road through a district that does not have very heavy hauling, the expense of a wide road bed would probably be prohibitive. But upon roads approaching a center of distribution it would seem that the wider road bed would be economical, for undoubtedly the grinding off of the edges of an improved road will rapidly wear out a road of this character.

On the question of road improvement in general, there are many difficulties that the engineer has to contend with. Usually the original roads were built following property lines without regard to grade or alignment. When the time comes for permanent improvement, the buildings, fences and other improvements limit the road to a certain route where any changes would necessitate very expensive work if there were much deviation from the old alignment. Anyone who has traveled over the roads in Western Pennsylvania will encounter these conditions continually.

As to the clay of Allegheny County, that is not confined alone to Allegheny County but is in all the western section of the State, I agree with all Mr. Whited has said about it.

A great deal might be done on country roads that cannot stand the expense of macadamizing, by a little engineering work in the way of providing drainage, and a little care in what improvement work is done. The ordinary method of road work under the old supervisors, was to use a plow and scraper and pull up the mud and stone that had been washed into the ditch the year before, and after the first rain things are in as bad a condition as they had ever been, while the same amount of money expended in permanent work would put many a country road into excellent condition. This condition of things exists all over this western section of the State. In the coke regions a great deal has been done simply by scattering coke ashes over the roads. The water drains from it and it makes a sort of amalgam with the clay, so

that many of the worst roads have been very materially improved.

WILLIS WHITED—In the vicinity of Pittsburgh there are plank roads that charge toll, although the road is too narrow for teams to pass without one of them leaving the planks. Near Montreal, Canada, they have macadam roads wide enough for teams to pass and they have to be kept in good order too, or they cannot charge toll. In the winter they have to open a passage through the snow drifts within 24 hours or they cannot charge toll. Still they pay dividends, and the vicinity of Montreal is not as thickly populated as the vicinity of Pittsburgh.

V. R. COVELL, Member—Roads in Iowa are treated with the split log drag, which some think the remedy for all evils in road making. Whether it is practicable here or not is a question. The tool is simply a split log drag for keeping the ruts filled.

WILLIS WHITED—That was evidently a dirt road and the purpose of the log was to fill up the holes and keep them full. With some kinds of soil that is all right but with others it is not. The greater part of Iowa is well adapted to that kind of treatment, not clay enough to make it sticky and sandy enough that it drains quickly, so that except in the softest weather it dries hard.

THOS. J. WILKERSON, Member—They are using the drag a great deal in the west, but it will not do if the road is not properly drained. In some parts of California they are using oil for improving the road. They use a heavy crude oil and put on two or more coats, it gives a very fine surface and prevents dust.

WM. MARTIN—I have seen oil used and it makes a good road. They have a rubbery surface like a soft cushion and no mud, winter or summer. I saw one piece of road that had been built four years and was informed that it had not cost a cent for repairs in that time.

WILLIS WHITED—There is a very important difference between roads in Iowa and roads here. Dirt roads on a

grade will wash lengthwise in deep ruts and the only way to stop it is to put something like stone in that will not wash out. Where you have level ground it is a different problem.

R. A. CUMMINGS, Member—A few years ago I constructed an accommodation road while developing some rock asphalt mines in Kentucky. We took the natural rock asphalt out of the quarry and broke it in place on the road, resulting in an asphalt road of excellent surface through the woods.

WILLIS WHITED—The best road I ever saw was in the vicinity of New Haven, Conn., where they used oyster shells. There is one street in this town that is covered with slag from a blast furnace, and where it is thick enough it is an excellent road.

H. C. BABBITT, Member—I think of all the muddiest mud and clayeyest clay in this state the worst is in Delaware County near Chester. Fifteen years ago they used to haul blast furnace slag on the side streets of the town. The result was that those streets became almost as hard as macadam, as in time there was a formation of the silicates of lime, etc., the same as you find in the large cinder banks. The slag was hauled hot.

M. A. TENNEY, Member—In Maine they have some sticky clay roads on which they use clam shells. In 1899 I was in charge of some macadam street construction in the city of Havana. On the advice of one of the inspectors I sprinkled a long stretch of suburban road with salt water. Another inspector used fresh water to sprinkle the adjacent section connecting with mine. It took about two weeks to thoroughly salt the road and after that we did very little sprinkling, while the other inspector had to sprinkle with fresh water two or three times a day to keep the dust settled.

When I had to dig up any of the macadam road it seemed to be like a piece of concrete. In fact there was an arch formed in one of the very narrow streets (a 25 foot street) where there was an underground drain (called a sewer) that got plugged up so that it scoured out quite a hole. On

inspection I found the sewer had burst and that the cavity was from three to four feet deep with a crust of macadam, probably three or four inches thick. A 10-ton roller had been passing over that crust for several hours before it broke through.

All the roads going out of Havana at that time were good roads, well shaded with trees that looked like our maple tree, and you could ride a bicycle for miles with hat off and hands off the handle bars. I have ridden twenty to forty miles straight away through the country on such roads with trees on both sides, and all the roads had very easy grades.

Robt. A. Cummings—In the Bermuda Islands the roads are cut out of coral rock, in some places 40 feet deep with vertical walls. The foundation of the roadway is the porous coral rock, broken to 3 inch size and placed 10 inches thick, over which is distributed clay soil filling up the uneven places. The finer screenings of the broken coral rock are spread over this foundation about 3 inches thick and thoroughly wetted down and rolled with a 10 ton Aveling and Porter road roller until it is smooth and hard. These roads are hard, durable, and altogether the finest roads I have ever traveled over. They very much resemble an asphalt street as to smoothness and freedom from dust. Repairs are easily made with a mixture of broken stone and clay.

Salt water has been used for sprinkling roads in many cities. Salt has a natural affinity for moisture and it keeps the road surface damp.

Wm. Martin—The steel rails on the Allegheny and Butler plank road were put down by the turnpike company. The road has since been taken over by the county. The rail is laid right on the ground with eight inches of broken stone underneath it. On the road near Louisville we just cut the macadam and filled up the cut around the supports and up to the top of the rail with concrete. On the Etna road there is about two feet of macadam on the outside of the rail.

G. H. DANFORTH, Member—Isn't that a case of building a special road to accommodate the horse and leaving out of account the other vehicles?

I was on the Butler road a short time ago and my impression was that the automobiles wanted to keep off the steel road. Water and mud would make it very slippery and there would be some danger of cutting the tires.

WM. MARTIN—There are no sharp corners and I cannot see how there would be any danger of cutting the tires; nor can I see how automobiles would slip on it as much as an ordinary mud or sand road.

G. E. FLANAGAN, Member—It will, perhaps, be pertinent to the subject at present under discussion to bring up the question of narrow or wide tires, and the desirability of having legal restrictions defining the size of tires to carry certain loads. There are certain conditions under which wide tires require greater tractive force than narrow ones.

In case there is a large percentage of wet clay upon the surface of a road, wide tires do not appear to free themselves from it as readily as do narrower ones, but this is an exceptional condition. Whatever may be said from the standpoint of vehicle construction and propulsion, I believe from that of road-bed maintenance the advantage is entirely upon the side of wide tires.

MORRIS KNOWLES, Member—I think the wide tire is decidedly the tire to use on a road that is macadamized. If there is a tendency at all to vary the line of travel it helps all the more to roll down and smooth the ruts. I noticed some teams recently, hauling heavy loads over soft ground, that made me think the wide tires did more harm than the narrow ones. The wagon wheels would cut through the soft ground for a depth of six or eight inches to a hard stratum underneath and the wide tire picks up a great deal of material, so much so that we found a great deal of material transported by the wheels to another place on the line. The narrow tire will not cart off material in that way.

WILLIS WHITED—That is a point depending very much on the kind of soil. A very thick clay will adhere to the wheels any way. With a very sticky soil it doesn't make much difference whether the tire is wide or narrow. Where there is a hard subsoil at moderate depth of course the narrow tire works best.

J. A. MCEWEN, Non-Member—I happen to know something of the teamster's view of this subject, and I find they object most strenuously to adopting wide tires. In winter time when the mud is deep on the by-roads it collects and freezes on the wheels, until, with the wide tire, the mud becomes a load in itself.

A point I wish to mention is the cementing of the surface of the road. From what I have seen of country roads they wear much faster in dry than in wet weather. When the road gets very dry the surface seems to chop up and get dusty and wash, or blow, away. The question of getting the best surface, and putting it in the best way to make it cement, is certainly a most serious one.

G. E. FLANAGAN—Some years ago I was called upon to examine a unique kind of road bed, more especially designed for city streets, being too costly to be considered for country roads. It was a road made of a vegetable fiber such as rank grass, and the people who were advocating it claimed that they could make it of straw or hay, but it was especially designed for a kind of rank grass that grew in the swamps of the South and could be had for the cutting. The method of construction was to bind the grass very firmly together, then cut it into blocks four or five inches high and twelve or fourteen inches square and coat the blocks with some sort of surfacing like cement or concrete which penetrated to a depth of not more than one-half inch. The argument advanced was that we had always proceeded on a wrong principle in making road beds, that we made them too rigid, what was needed being a hard wearing surface and a cushion underneath.

The only phase of the question which I was required to consider was the design of a press of such a construction as would render the forming of these blocks commercially profitable. They were required to be made under very great pressure, sheared to uniform length, and fastened with a binder which would prevent them expanding when the pressure was released, the form required being square or rectangular.

H. C. Babbitt—I saw similar blocks in Philadelphia a number of years ago where they took prairie grass and dipped it into a sort of asphaltum so that it penetrated a half inch or an inch. At that time, though I did not see it, a claim was made that a section of these blocks had been placed in West Philadelphia that showed absolutely no wear at the end of a year. The calks of the horse's shoes would make an indentation, but by morning it would resume its original shape. But they had two troubles, first to get some one to handle it financially, and second they did not know how to accommodate themselves to the different sized blocks required to fill in a pavement. Their claim was that they could not chip it and they would have to have hundreds of sizes and shapes to fill out a road.

M. A. Tenney—I have seen many miles of road repaired with huckleberry bushes cut up and put into ruts, and they will last several years. When they are once packed they make a very good road.

*STEEL BARGES.

† RICHARD J. DONOVAN.

Non-Member,

In opening this discussion I will present some facts concerning river transportation that we may get some idea of the conditions of service met with in this business. I would here state that we may divide the business of transportation into two general classes: First, that which pertains to bulk quantities, including such staple articles as coal, steel, grain, etc.; Second, that which pertains to package quantities, including the general run of merchandise which may come in some form of package, or in quantities which will not warrant special shipment. We find that, in the case of the first class, viz: bulk quantities, the problem consists in simply loading the article considered in some type of carrier and delivering at some destined river port, without breaking or shifting individual cargoes. With the second class, viz: package freight there is more or less shifting or breaking cargo with additions, or subtractions, at various points.

Of course the handling of bulk quantities is by far the most interesting problem to the engineer, and it is here that the observer is astonished at the magnitude of such individual movements on our rivers.

For the benefit of those of us who are not sufficiently acquainted with the volume of traffic on the Ohio River, I thought it would be interesting to present a few facts concerning this matter. The total navigable mileage of the Ohio and all its tributaries is about 4,400 miles, the Ohio itself being about 1,000 miles from Pittsburg to Cairo where it empties into the Mississippi.

The gross freight movements on this vast waterway system amounts to about 11,000,000 tons per year, the coal

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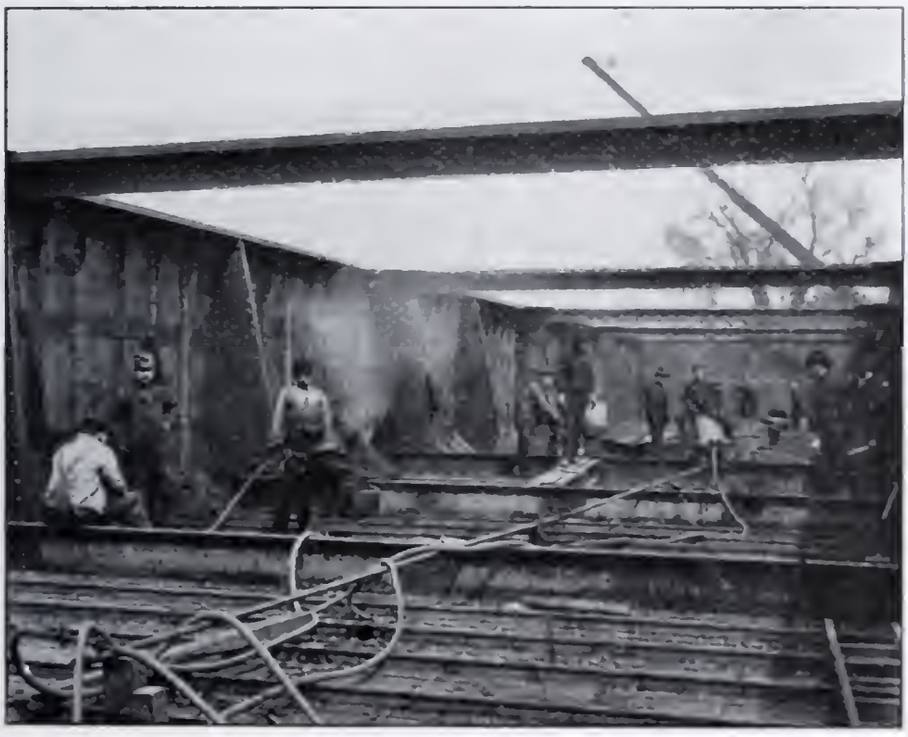
* Meeting of Structural Section, October 24, 1905.

† American Bridge Company, Pittsburgh, Pa.

from our Pittsburg district constituting about half of this tonnage. In handling this enormous business, there are employed about 480 steamboats of all descriptions and some 6,000 or 7,000 barges. I might add that one company here in Pittsburg, the Monongahela River Consolidated Coal and Coke Company, own upward of 100 tow boats of all descriptions together with 3,000 barges, and ship annually about 4,000,000 tons of coal.

The various types of carriers used on this great system may be divided into two classes: First, those provided with



their own propelling machinery, such as the stern and side wheel steamboats. Second, all carriers that have to be towed, or moved, by external means, such as the coal barge, or decked merchandise barge. We would here note that there is a large number of craft used in maintaining traffic, such as dredges, snag boats, derrick boats, repair and pump boats, etc., which we will touch on later. These two general classes are the result of many years' experience and hard thought on the part of those engaged in the river business, and I may add that the types adopted are peculiarly fitted for the service.

The final result in any design for a carrier on any waterway system is a compromise between adaptability for certain speed, draft of water available and carrying capacity required, there being of course many other details peculiar to the service conditions.

The requirements for a river steamboat then may be briefly stated to be (taking first the case of the packet steamer) such speed as has been found economical for the service engaged in, the least possible load draft, and such freight and passenger capacity as the usual run of business would warrant. In the case of the tow boat, large reserve propelling power is an important item and, due to the fact that coal barges leak more or less, there must be a large excess in boiler capacity for the purpose of operating the steam siphons which are used to keep the tow clear. The under water parts of the tow boat hull are, as a rule, not so fine as a packet boat, that is, they are not formed for such speed. They are not intended to carry cargo, and the accommodations provided are generally but little in excess of those required by the crew. The boats are well supplied with all kinds of appliances and machinery for handling the tows, and in the intricate and shallow channels are admirably suited for the purpose intended.

In bulk transportation we have seen that coal is far in the lead as a staple product, and we will now present a short account of the carriers used in this trade. These carriers are divided by the rivermen into two classes known respectively as the "barge" and the "boat" both of which are rectangular in plan and resemble large open boxes. The ends of both are usually curved, or raked, from the bottom to the head blocks, as the ends which take the bumps and shocks are called. Bulkheads are fitted in some at each end separating the rake end from the main cargo space. In passing I would state that the barge is mainly used in the Cincinnati & Louisville trade, while the boat is employed almost exclusively in the Mississippi River business. The barge is usually about 135 ft. by 26 ft. by 8 ft. and will carry between 15,000 and

16,000 bushels, or nearly 600 tons, on a draft of about 6 ft. 6 inches. The boat is usually about 170 ft. by 28 ft. by 8 ft. 6 inches, and will carry about 25,000 bushels, or 950 tons. The barge is built in a very substantial manner and will last for some time, but the boat is merely thrown together and can stand but little hard usage. For some kinds of cargoes, such as sand and bulk merchandise, deck barges are used. These are of various dimensions and built to stand the hardest usage.

There is also a very important business on the Mississippi River in the transfer of railroad cars from side to side. These car ferries, or transfer boats are generally of large dimensions and are supplied with their own power. There is also in use a number of transfer barges built in the most substantial manner especially for this business.

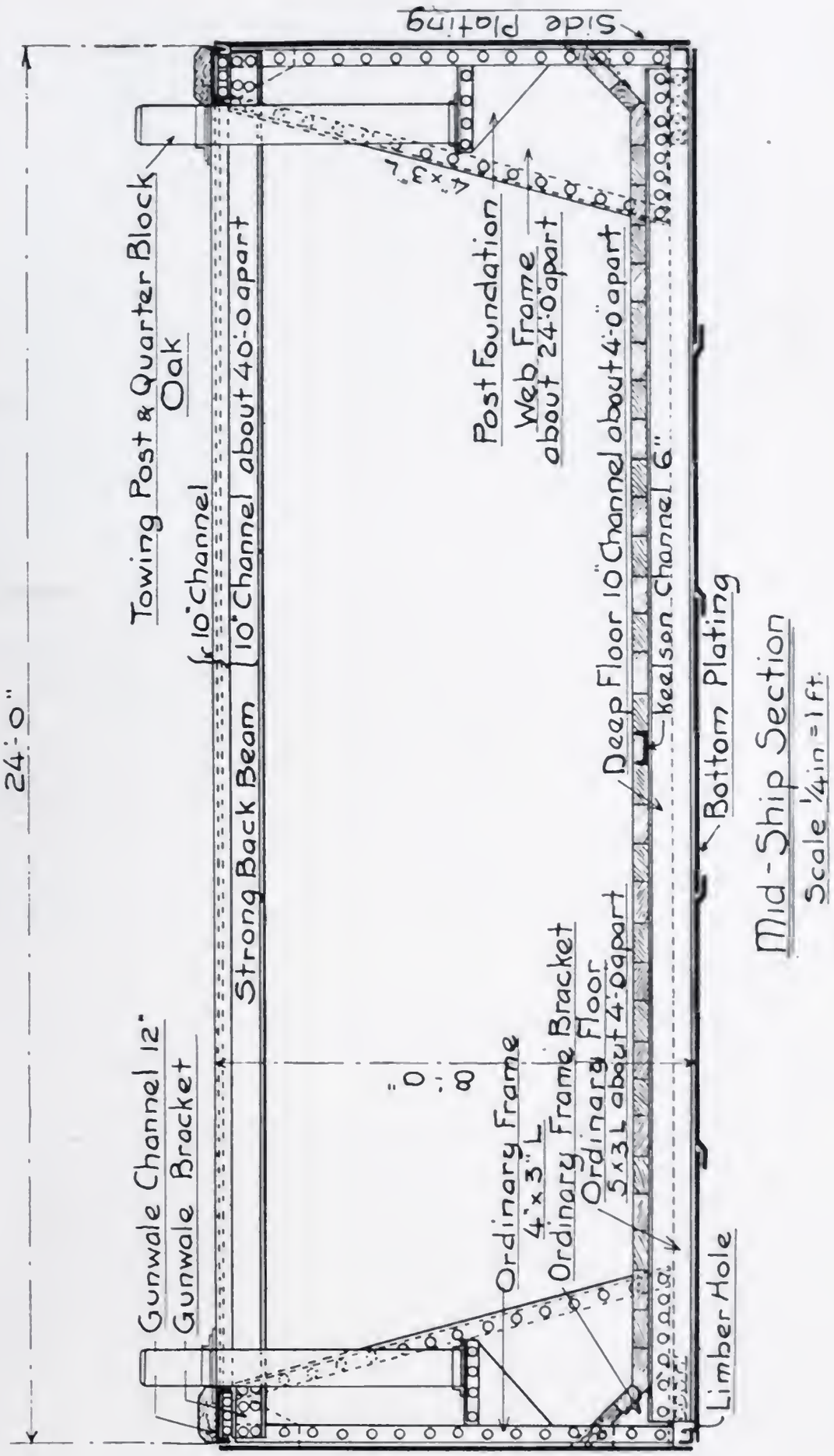
Up to the present time, wood has held its own in river construction on account of its cheapness, for the wooden structure costs but one half to one third as much as the steel structure. However, suitable timber is becoming very costly on account of its scarcity, and the large operators are beginning to investigate the relative advantage of steel

for their transport fleets. At present there are several examples in steel of the various types discussed operating on the Ohio River, and experience has shown that the steel hull is far superior to the wooden hull in cost of upkeep while its life is double that of the wooden.

We will now examine the construction of a typical steel river steamboat. The general principle involved in the construction of any type of boat is usually embodied in arranging a longitudinal "backbone" consisting of longitudinal bulkheads, keelsons and stringers. At right angles to the "backbone" is arranged a system of "ribs" or transverse members, consisting of floors, side frames, deck beams and cross-bulkheads. The shell, or outside plating, is then riveted to the skeleton frame. The bulkheads and shell plating are fitted watertight, this being accomplished by proper spacing of rivets and judicious use of caulking tools. I would here note that some very interesting construction is required to insure watertightness, but as a rule, in shallow draft river crafts, the water pressure is so low that it is not at all difficult to solve the problem. A complete, or partial, steel deck is usually provided, and on this steel foundation the wooden cabin and upper works are built.

There is also usually provided a "Hog Chain System" to insure longitudinal strength. This is a truss arrangement consisting of a square or round section rod carried over tube or timber bracing and leading from the bow of the boat to the stern. It usually projects above the cabins and is quite apparent. The aim is to make the structure as light as possible consistent with the required stiffness and strength for the service conditions.

It is perfectly feasible to make an analytical study of the structure of a boat, but in river work such an investigation, using the sizes and sections fitted in the best work of this kind, would show a most amazing confidence in steel, and would probably deter the exact scientific engineer from competing in this line of work.

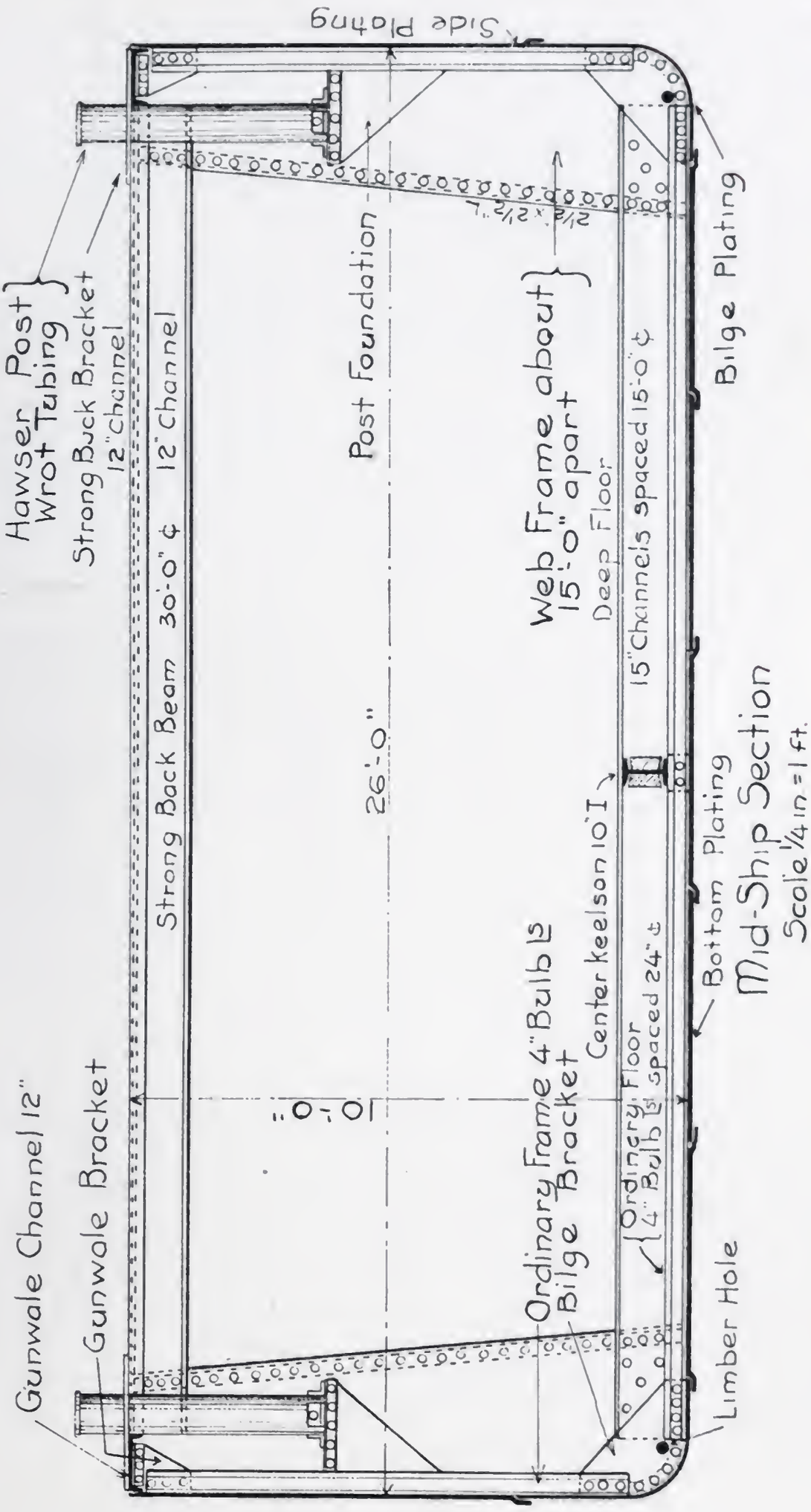

Side plating
4"x3"L
Towing Post & Quarter Block
Oak
10" Channel
10" Channel about 40'-0" apart
Post Foundation
Web Frame
about 24'-0" apart
Deep Floor 10" Channel about 4'-0" apart
Keelson Channel 6"
Bottom Plating
24'-0"
Strong Back Beam
Gunwale Channel 12"
Gunwale Bracket
Ordinary Frame
4"x3" L
Ordinary Frame Bracket
Ordinary Floor
5x3 L about 4'-0" apart
Limber Hole
Mid-Ship Section
Scale 1/4 in = 1 ft.

The tow boat hulls are made much stronger than the packet boat hulls, since they have to stand much harder usage in every way besides carrying much heavier machinery.

Now let us consider a steel open "boat" or "barge" for the transportation of coal. The same principle is carried out here as in the case of the steamboat hull—viz, the "backbone" and "rib" construction—but here we have to depend more on the sides of the "boat" or "barge" acting as the "backbone" or longitudinal girders—for the interior or hold space must be available for cargo. The ends are usually curved up to heavy end construction known as the head block, which takes the bumping and blows incidental to the rough service. This curved part is called the "rake" by rivermen and is introduced to ease the passage of the boat through the water. At the foot of the rake at each end, a watertight cross bulkhead is usually fitted for safety purposes. The framing of the rake must be of a very substantial character as it is here that the barge suffers most. The cross frames or "ribs" are spaced about 2 ft. apart in the cargo space, and at certain intervals there are beams fitted across the barge to stiffen the sides. The barge is merely a shell, and of course some judgment must be used in unloading or loading the cargo in order to place no undue stresses in the structure.

The following general description refers to a type of steel coal barge of which a number have been built and are now in use.

The steel plating used in these barges is all about ¼ inch in thickness and the cross framing or "ribs' consists of channels and angles fitted alternately, except the side frames which are angles. A steel watertight bulkhead is fitted at each end of the cargo space, and a steel handling deck is arranged from top end of bulkhead to head block. A heavy channel is fitted at the top of the side plating for lateral stiffness, and strong beams are fitted across the open cargo space at the quarter block or hawser posts. As the clam-


Side Plating
Hawser Post
Wrot Tubing
Strong Buck Bracket
12" Channel
Strong Back Beam 30'-0" ℄
12" Channel
Post Foundation
2½" x 2½" L
Web Frame about
15'-0" apart
Deep Floor
15" Channels spaced 15'-0" ℄
Bilge Plating
26'-0"
Center keelson 10" I
Bottom Plating
Mid-Ship Section
Scale ¼ in = 1 ft.
Ordinary Frame 4" Bulb Ls
Bilge Bracket
Ordinary Floor
4" Bulb Ls spaced 24" ℄
10'-0"
Gunwale Channel 12"
Gunwale Bracket
Limber Hole

shell, or unloading bucket, is used in taking out the coal, a wood flooring, or ceiling, is laid on the channel floor beams, thus presenting a smooth surface for the unloader.

These barges have given good satisfaction to the owners and are said to hold about 80 tons more coal than the wooden barge of the same dimensions and draft.

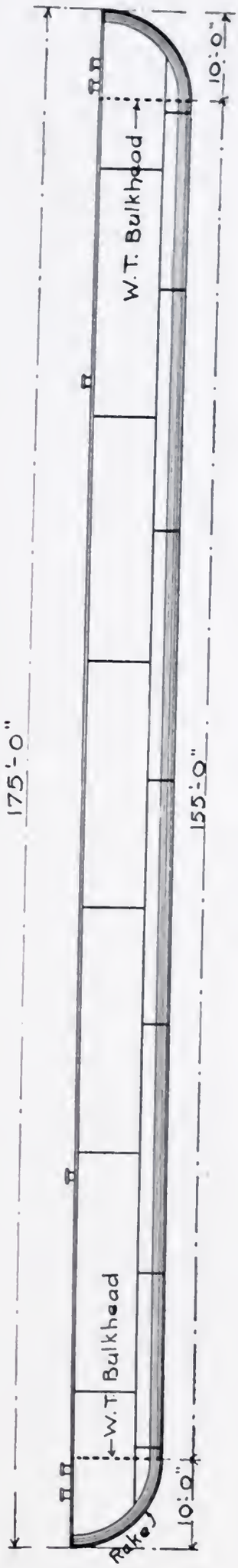
In the construction of steel deck barges, care must be taken to make the internal framing sufficiently strong to care for the general longitudinal stresses, and also for those that are local.

The conditions of service met with in dredge hulls are such that usually the local loading and stresses are very high, so that we have to deal, not so much with general as with local stiffening; but the general construction of such hulls is identical in principle with that which we have already discussed.

In the matter of upkeep, the preservation of steel plating and framing from oxidization is of the highest importance, and it is here that a great deal of trouble and expense is incurred. Due to there being so many manufacturing plants established on the banks of the rivers forming the Ohio large quantities of acid matter are drained into the water, giving rise to conditions which are highly injurious to the life of the steel river craft. The use of some good protective paint or covering is imperative, but such a paint is hard to find. There are, however, some such coverings which seem to hold in check this acid to a marked degree.

In conclusion, I would state that at present the business of transportation on the Ohio River is a speculation, depending entirely on the stage of water. The Government is working to improve this state of affairs by a series of locks and dams along the whole length of the river. In time, it is hoped, that an eight or nine foot stage of water will be available the whole year, but it is said that this work will cost nearly $100,000,000 and will require about one hundred years for completion. In the old days before the Civil War, the Mississippi and Ohio rivers were crowded with packets

Outboard Profile



Outboard Profile

and freighters and an enormous river business was carried on, but the railroads have now taken over the most of this traffic, and the rivers are lined with the decaying remains of this once vast fleet.

DISCUSSION.

C. N. Haggart, Member—Are hog chains necessary with a steel boat or are they only used with a wooden boat? I should think longitudinal bulk heads could be made strong enough to take up any strain.

R. J. Donovan—It would be entirely possible, though not always desirable to do that. It is sometimes desirable to have a flexible construction. In car ferries, however, they make the bulk heads of girder construction to stand the strain.

J. Blodgett, Member—Do barges have to be lined to prevent the sulphur in the coal from acting on the steel?

R. J. Donovan—Up to date there are only a couple of steel barges in use, and I understand that the only precaution against the action of the coal is to coat the inside with heavy oil. On some barges that have been built for carrying coal there has been used a special acid-proof paint. Of course the barges have not been in use long enough to judge whether the paint is a sufficient covering to protect it against this action. But I will say that it is entirely possible to protect steel against any action arising from the sulphur in the coal.

E. K. Morse, Member—How often do these barges have to be dried out for painting?

R. J. Donovan—The steel barge would have to be dried out, or docked, at least once a year for examination and painting. It has been my experience with boats carrying a much larger tonnage than the ones under discussion that that has been sufficient.

Arnold Stucki, Member—Have you found a special brand of paint, or have you any special ideas with reference to that subject?

R. J. DONOVAN—I would not mention any particular brand, although I have tried several, but think a good graphite paint as good as anything.

E. K. MORSE—You adopt a false bottom in the barges. What are you going to do with that when it begins to rust?

R. J. DONOVAN—The wooden ceiling is laid in such a way that it can be taken out. This should be done once a year.

CAPT. JAMES MOREN, Non-Member—I have been in the coal business for twenty years and when the American Steel & Wire Company wanted to build some barges they asked me what I thought of steel barges, I told them it was the only barge to build. After that they asked me why we didn't build them as we had been in the business so long. We told them the only reason was we didn't have money enough. So they had the American Bridge Company build ten for them.

The first barge has been in use about two months and has proved very satisfactory. I think it is the coming barge, if they could only get the prices down where we can afford to buy them.

E. K. MORSE—What depth of water will steel barges draw, and do they require as much as wooden barges?

CAPT. MOREN—It will carry more than a wooden barge requiring the same depth of water. We haven't had one loaded to its full capacity yet, but it will carry from 75 to 100 tons more on the same depth of water.

E. K. MORSE—What are you going to do when you have a barge sunk, or grounded, in the channel of the river? You can't put dynamite under it and blow it out of the river.

CAPT. MOREN—No, you can't blow them out of the river, but it will not be any harder to raise a steel barge than a wooden one. When the wooden barges sink most of them go to pieces. With a steel barge you can bulk-head it up, or you can put chains under it and raise it that way. They will sink just the same as wooden barges. They will not, however, leak as bad. Wooden barges, after four or five

years' use, require a great deal of money to keep them in repair. Another thing, when we take a barge down the river in July, the barge is empty in a month and lies there three or four months, they have lain as long as five months, then when you come to get the barge in commission you have got to repair it before loading. You can get a steel barge loaded before you can get a wooden barge ready to load.

E. K. Morse—How about winter time, and running through ice?

Capt. Moren—The steel barge is what is wanted. At the present time we have to sheet the wooden barge with iron and when the ice is heavy we string out the barges, put the boat in the front and back it down. That wears the wheels out. About the second trip we have to rebuild the wheels.

E. K. Morse—Is there any particular shape that ought to be made regarding the form of the boat?

Capt. Moren—Put a long rake on the boats and it makes them a little easier to tow, while a round corner as they have on the boats at Ambridge is a great advantage in the lock. If we go in with a full head of steam, as we have to do when there is much wind in order to get the boats in at all, we generally put four barges in the lock at one time. If we strike the lock with a square corner the barge will be thrown around and block the lock, but if there is a round corner, it will slip off.

E. K. Morse—How are you going to take care of steel in water where there is so much sulphur, when we have so much trouble out in the air where it is easily accessible with the paint brush?

Capt. Moren—Consider the wooden hull steam boat to-day with sheet iron sheathing for use in the winter. I have had sheet iron on the Steamer Juniata for four years and took it off this summer. The iron was cut through in several places, but it was not cut through from acid. The hull was under water all the time and the sides partially so. We

have trouble with the acid eating rivets and calking out of boilers, but I think you have got to boil the water to do it, at least that is the theory I have. It doesn't eat the iron on the side of the boat, but it does the boiler.

ARNOLD STUCKI—I understood Mr. Donovan to say the steel boat has twice the life of the wooden boat. It looks to me as though it would have four or five times the life.

R. J. DONOVAN—That is the least; it is actually more. I wanted to be on the safe side in my statement.

CAPT. MOREN—We figure the life of a wooden boat or barge at ten years. It is necessary to put on a lot of repairs in ten years. At the end of that time a barge is about done. Then they patch it up, load it south and sell it.

E. K. MORSE—Is there any way of overcoming this nuisance of a false bottom. You have to take it out once a year. Isn't that going to destroy the life of the false bottom?

CAPT. MOREN—A lot of lumber is going to be lost each time, and of course that will cost something. You have to have a dunnage in the barge. In the other markets it is never used, but in the Pittsburg market we have got so used to the dunnage that they will not unload a barge where the coal is filled right in on the bottom.

E. K. MORSE—But it seems to me that is not in keeping with the permanency of the structure. You are building a steel structure for permanency and putting it up against a wooden structure on that basis, yet you are pulling the bottom out once a year.

CAPT. MOREN—I have thought of pouring in heavy crude oil and see if that will not keep it from rusting.

L. J. AFFELDER, Member—Would it not be advisable to put in a steel dunnage.

CAPT. MOREN—A steel dunnage is what you want. It would not be as hard to lift as a wooden one and it would be lighter.

F. R. JENNINGS, Member—Would not a steel dunnage be very hard on the "clams" getting the coal out?

CAPT. MOREN—I do not think it would be as hard on the "clams" as wood. You could make it so it would be easier to get the coal out than with wood.

W. M. JUDD, Member—The first speaker mentioned coal boats and barges, the coal boats being of lighter construction. Is there a special place where the coal boats are used, or are they used interchangeably for the same traffic.

CAPT. MOREN—The coal boat is mostly used in the New Orleans trade. We always use the wooden coal boats in that trade because we never expect a coal boat to make over two trips. The barge is mostly used in the Louisville and Cincinnati, or St. Louis trade, as we tow them back. The barge is built out of better material and lasts much longer. We take coal to New Orleans and the coast and sell it for so much a barrel and that includes the package. The planter who gets the coal gets the boat when he unloads it. If it is unloaded in good shape we buy the boat back from him for the least we can get it and tow it back. The idea is to get towing for the boats and also to keep the price of boats down in this market. We have to pay the pilot so much for making each trip whether he comes back empty or with ten or twelve boats. They are supposed to make the trip in thirty days, sometimes they make it in 29, but if they come back light they get the same money as if they bring back a tow.

J. BLODGETT—Do you now tow coal boats up the Mississippi River?

CAPT. MOREN—You could not tow a coal boat up the Mississippi River, it is too light. A coal boat has only 1½ inch sides. Barges are preferred to the coal boats on account of the unloading. With a coal boat if you unload too much out of one place it will make a leak.

L. J. AFFELDER—During the past six months I have talked with many people regarding the use of steel in river transportation and it is surprising to learn their views. I think they are all in accord that steel should be used and they all have ideas as to what the construction should be.

And they are all in accord as to the cost being too high. That seems to be the stumbling block. In answer to Captain Moren I would say that if sufficient coal boats or barges are built, the cost will take care of itself. The trouble with all buyers and prospective buyers is that they are not satisfied to purchase a standard boat, nor are they satisfied to purchase them in sufficiently large quantities. Every buyer, or prospective buyer, while he in general agrees as to what is to be used, wants something just a little different from his neighbor, and that is what increases the cost of boats. Just as soon as boats can be standarized, as steel cars are, then the river man will be able to buy a boat cheap enough to warrant him in discarding wooden boats altogether; but until they do so they cannot expect to buy a cheap boat.

The principal obstacle I have found in trying to sell these boats is the question of cost and not the question of life, or paint, or sulphur, or water, only the question of cost.

E. K. Morse—That is all right as far as your side of it is concerned. You want to sell those boats and get all the money out of it you can. That is natural. You say that the question of rust or of paint, etc., does not concern them. But it strikes me that is one of the very points that will concern them.

L. J. Affelder—What I meant by that was that they are able to cope with those other questions.

R. J. Donovan—There is one barge, owned by the Monongahela River Consolidated Coal & Coke Co., that has been in use since 1891, about 14 years. That is a wrought iron boat, not steel, but it has given excellent satisfaction up to date, and I understand the amount of money spent in annual repairs on that boat is very small indeed. I understand that rusting, sulphur, and things like that do not affect it at all.

Arnold Stucki—It seems to me that the boat builders are now in exactly the same position as the car builders were

eight or nine years ago, when they had to compete with the wooden car. At that time every detail had to be made as light as possible, consistent with strength and safety, while now oftentimes a great deal more material is put into the same details, because the purchaser has learned to appreciate the advantages of steel over wood and is willing to go one step further, knowing that the increased additional cost is more than offset by the increased life, provided the metal is distributed properly.

*HEAT INSULATION; ITS PRINCIPLES AS RELATED TO COLD STORAGE PRACTICE.

† J. B. d'HOMERGUE.
Non-Member.

The subject of insulation is a very interesting and important one, not only from the standpoint of economy, but because it contributes so much to the comfort of human life. It has made it possible for the inhabitants of one clime to enjoy many of the products of other climes. Those living in temperate zones feast upon the fruits of the tropics and vice versa. Besides these advantages, it provides a means of keeping the products of a season of plenty that they may be consumed in a season of scarcity. Indeed, when one considers the value of insulation in its relation to modern life, one is struck with the important part it plays in almost every department of our domestic economy and comfort.

The principles of insulation have been studied from the earliest times, and a sort of inherent instinct as to their application, although in the crudest way, must have been implanted in the minds of Earth's first inhabitants. From time immemorial, people have protected themselves from climatic extremes through the utilization of the principles of insulation. The science of insulation as such, has, however, been but little understood until within comparatively recent times, when its economical relation to applied mechanics compelled attention.

It is doubtless within the memory of those present when the factory using pipe-covering was the exception. To-day this condition is reversed. Pipe and boiler covering, or that branch of insulation applying to the economical production

* Meeting of Society, December 19, 1905.

† 74 John Street, New York.

TABLE I.

ARCTIC KEYSTONE.

OBSERVED RESULTS.

DATE	Hour Ending	Average Temperature on Inside of Panel	Average Temperature on Outside of Panel	Weight of Ice Melted Per Hour Pounds	REMARKS
I	II	III	IV	V	
Nov. 7	11:45	49	85.1	1.56	Ice Chamber
"	12:45	49	89.2	1.50	Filled 9:00 A. M.
"	1:45	49	90.7	1.56	
"	2:45	49	92.1	1.57	
"	3:45	49	92.5	1.63	
"	4:45	49	92.5	1.63	
Nov. 8	10:15	49	87.9	1.69	Ice Chamber re-filled 7:00 A. M.
"	11:15	49	89.5	1.66	
"	12:15	49	90.5	1.59	
"	1:15	49	90.5	1.66	Test Observations
"	2:15	49	90.5	1.66	
"	3:15	49	90.5	1.66	
"	4:15	49	90.5	1.69	
TOTAL - -		343	629.9	11.61	
AVERAGE - -		49	89.6	1.66	

and use of steam, is too well understood to require consideration in this paper. I will therefore start at a point beyond the engine. In other words, I will treat only of insulation as bearing directly upon artificial refrigeration, whether the refrigerating effect is produced by natural or mechanical means.

The advent of cold storage as a business whether in stationary plants, on board vessels or in refrigerator cars, is a thing of to-day. As a commercial proposition it has proven itself. On this account, it has stimulated research and invention until a modern cold storage plant stands as a model of engineering skill.

At first, the greatest development was along mechanical lines, but this was soon followed by progress in the collateral branch, that of insulation. It was soon apparent that the action of the best machinery, or the refrigerating effects of the best ice, were very largely nullified unless efficient insulation backed up the refrigerating effort. By the word insulation, we mean the materials composing the walls of a refrigerated space, that which resists the passage of heat from the outside to the inside.

Refrigeration is nothing more nor less than the process of extracting heat and, as used commercially, its application to perishable products. The methods by which this can be done most economically is the subject of study by many engineering minds the world over.

To secure this most desired economy, the maximum of effort should be directed to refrigerating the products to be chilled and only a minimum to refrigerating the containing structure itself. Stated more concretely, the walls of a cold storage structure should contribute as little heat as possible to the sum total to be extracted by the refrigerant. It has been stated by some authorities, that three-fourths of the refrigeration applied to cold storage rooms, is spent in removing the heat which leaks through the walls. I am not prepared to endorse this statement, especially so far as recently

TABLE II.

TWO LAYERS.

ARCTIC KEYSTONE.

OBSERVED RESULTS.

DATE	Hour Ending	Average Temperature on Inside of Panel	Average Temperature on Outside of Panel	Weight of Ice Melted Per Hour Pounds	REMARKS
I	II	III	IV	V	
Jan. 17	10:00	47.3	88.8	1.06	Ice Chamber filled 4:00 P. M. Jan 17 and refilled 8:00 A. M. Jan. 18.
"	11:00	47.3	89.0	1.13	
"	12:00	47.3	90.6	1.38	
"	1:00	47.3	90.3	1.38	
"	2:00	47.3	90.3	1.38	
"	3:00	47.3	90.0	1.41	
"	4:00	47.3	89.8	1.38	
Jan. 18	10:00	47.3	88.8	1.38	Ice Chamber refilled 7:00 A. M.
"	11:00	47.3	90.0	1.44	
"	12:00	47:3	89.0	1.44	
"	1:00	47:3	89.2	1.44	Test Observations
"	2:00	47:3	89.4	1.44	
"	3:00	47:3	89.0	1.47	
"	4:00	47:3	90.0	1.44	
TOTAL - -		331.1	625.4	10.05	
AVERAGE -		47.3	89.3	1.435	

erected plants are concerned, but that the loss is very much greater than is generally believed I have no doubt.

The importance of good insulation is now so well understood that specifications are all along lines of seeming extravagance as to first cost, efficiency being, apparently, the chief consideration. In fact the present tendency is towards the ideal wall, although there is a wide divergence of ideas as to how this should be constructed. Opinions differ as to what materials should be employed and also how they should be combined. It is generally recognized that the best insulation is none too good, for the investment for walls has to be made but once while the refrigerating expense is continuous. The smaller this expense, the more successful the administration.

Tyndall defines heat as vibration in the luminiferous ether supposed to pervade all matter and all space. Occurring in the form of vibrations, its motion has wonderful penetrating power and seeks to establish a level of temperature. Such motion proceeds best through a uniform medium. Transition from one medium to another of different density retards and dissipates it. The vibrations seem to adapt themselves to the density of any substance they enter and to travel easily until they meet a different substance, or stratum, when they have to modify themselves to suit the new density before proceeding further.

This is well illustrated by Tyndall's experiments on thirty-two kinds of woods. He found three co-efficients of conductivity for heat; that conduction was more than twice as great along the grain as across the grain and tangent to circles of annual growth; that it was 10% to 25% greater in the last direction than from the surface to the heart of the tree, due doubtless to variations in density between the inner and outer stratifications. Therefore an insulated wall should be composed of several layers of unlike materials, to retard the heat waves which must undergo change and loss with every transition from one material to another.

TABLE III.

LINOFELT.

OBSERVED RESULTS.

DATE	Hour Ending	Average Temperature on Inside of Panel	Average Temperature on Outstde of Panel	Weight of Ice Melted per Hour. Pounds.	REMARKS
I	II	III	IV	V	
Nov. 11	11:30	49.3	86.5	1.63	Ice Chamber filled 9:00 A. M.
"	12:30	49.3	88.0	1.66	
"	1:30	49.3	89.5	1.78	
"	2:30	49.3	90.0	1.78	
"	3:30	49.3	90.1	1.75	
"	4:30	49.3	89.5	1.78	
"	5:30	49.3	89.4	1.78	
Nov. 12	9:15	49.3	89.6	2.09	Ice Chamber re-filled 6:30 A. M.
"	10:15	49.3	90.1	1.90	
"	11:15	49.3	91.8	2.06	
"	12:15	49.3	91.5	2.00	Test Observations
"	1:15	49.3	91.5	2.03	
"	2:15	49.3	91.2	1.96	
"	3:15	49.3	91.2	2.00	
"	4:15	49.3	91.0	1.94	
Total - -		394.4	727.9	15.98	
Average -		49.3	90.9	1.99	

It has been found impossible to entirely prevent the passage of heat through cold storage walls, but it has been proven that some forms of construction retard its progress more than others. By an apparent paradox in Nature, the best way to prevent the travel of heated air is to oppose it with air **not** in motion. Free air is never still, but moves as its density is changed either by the loss or gain in heat, loss or gain in moisture, or loss or gain of both heat and moisture. In order to secure motionless air, it should be confined so as to prevent its circulation. To best confine it, it should be divided into the smallest possible particles and stored in minute enclosing cells.

Heat is transferred from the outside atmosphere to the interior of a refrigerated space by three agencies, viz: convection, conduction and radiation.

Convection means the conveying of heat by a circulation of air. The air in contact with the outer side of an insulated wall is heated and rises, while that in contact with the inner side is cooled and falls. This gives it a rotary motion which conveys the heat from one side to the other. Of course, this process is reversed in severe weather when the outside temperature is lower than that of the interior refrigerated space. Convection in either direction, however, can be considerably minimized by building the wall according to well-known principles, i. e., of as many layers of unlike materials as possible. It is a factor of such great loss that it should not be left to chance. Before the losses by convection were appreciated it was customary to attempt to secure a combination of different densities by subdividing the wall into a number of layers of *unfilled* air-spaces. In other words to confine the rotary motion of the air to as small units of area as possible. Modern practice is more and more in the direction of filling the air spaces with fibrous materials.

Conduction is the direct passage of heat through any substance. Roughly speaking, it is a property possessed by heavy dense bodies to a marked degree and by light porous bodies to a less degree. Heat passes through a material by

TABLE IV.

TWO LAYERS.

LINOFELT.

OBSERVED RESULTS.

DATE	Hour Ending	Average Temperature on Inside of Panel	Average Temperature on Outside of Panel	Weight of Ice Melted Per Hour Pounds	REMARKS
I	II	III	IV	V	
Jan. 23	11:00	48.8	88.4	1.50	Ice Chamber filled 3:00 P. M. Jan. 22 and refilled 8:00 A. M. Jan. 23.
"	12:00	48.8	89.9	1.56	
"	1:00	48.8	90.0	1.56	
"	2:00	48.8	90.1	1.56	
"	3:00	48.8	90.0	1.62	
"	4:00	48.8	90 0	1.62	
"	5:00	48.8	90.0	1.62	
Jan. 24	10:00	48.8	89.5	1.66	Ice Chamber refilled 7:00 A. M.
"	11:00	48.8	89.5	1.68	
"	12:00	48.8	89.0	1.62	
"	1:00	48.8	89.0	1.62	Test Observations
"	2:00	48.8	89.0	1.62	
"	3:00	48.8	89.0	1.62	
"	4:00	48.8	88.8	1.62	
TOTAL - -		341.6	623.8	11.44	
AVERAGE -		48.8	89.1	1.634	

conduction in the same way as up the handle of a poker when the other end is inserted in a fire. This action is present in the walls of a refrigerated room, but in a degree not manifest to our senses. It is, however, a big factor of loss in cold storage operation, especially along the lines of contact of the more solid materials of the wall structure.

Radiation is the direct passage of heat through the air from one body to another. At the temperature employed in cold storage, we may almost ignore heat transmission by radiation.

The air in the walls of a cold storage structure should be kept dry, as water transmits heat almost forty times as fast as air. To secure dry walls is very difficult. The atmosphere always carrying moisture, if brought into contact with a colder surface, it is cooled and its capacity for moisture is diminished. If cooled below saturation, some of its moisture is condensed on the cold surfaces. In cold storage business, the amount of such deposit from the air is very great. It covers the refrigerating coils thickly with frost and gathers more or less on the walls. If they be waterproof, the moisture will be absorbed by the air after a time, but if not, it will be drawn into the pores and cells of the insulating material by capillary attraction.

From the foregoing it will be seen that the substance of a proposition for the construction of insulated walls for cold storage purposes involves the problems of overcoming convection, conduction and moisture; further considerations include the factors of cost, space and durability.

A recognition of these desiderata brings one naturally to the selection of those substances, or materials, which will best meet the conditions. It also means arriving at a method of utilizing them in such a way that they can be properly associated together to give the greatest number of changes of density, impose barriers to contact and resist moisture without conflicting with structural requirements as to stability and space.

TABLE V.

ONE-HALF INCH HAIR FELT.

OBSERVED RESULTS.

DATE	Hour Ending	Average Temperature on Inside of Panel	Average Temperature on Outside of Panel	Weight of Ice Melted per Hour Pounds	REMARKS
I	II	III	IV	V	
Nov. 29	10:15	51.3	89.2	2.94	Ice Chamber filled 7:00 A. M.
"	11:15	51.3	90.6	2.84	
"	12:15	51.3	89.9	2.88	
"	1:15	51.3	89.0	2.75	
"	2:15	51.3	89.0	2.50	
"	3:15	51.3	89.0	2.72	
"	4:15	51.3	89.5	2.63	
Nov. 30	11:00	51.3	89.5	3.25	Ice Chamber refilled 9:00 A. M.
"	12:00	51.3	90.0	3.28	
"	1:00	51.3	89.0	3.19	
"	2:00	51.3	89.3	3.16	Test Observations
"	3:00	51.3	89.0	3.19	
"	4:00	51.3	89.7	3.16	
"	5:00	51.3	89.5	3.19	
Total - -		359.1	626.0	22.42	
Average -		51.3	89.5	3.20	

That all substances contain some air we know, but we also know that some contain more than others. Porous and fibrous substances enclose more air than those of greater density. The reason is obvious. They are already filled with, or enmesh, large quantities of air and naturally lend themselves to insulation. They are not waterproof, but readily absorb water, and if saturated, their thermal conductivity is vastly increased approaching that of water itself.

Even in the number of substances naturally possessing great insulating qualities there is a difference in value for commercial use; they may be ideal insulators when dry, but have too great an affinity for moisture, or may deteriorate by the action of moisture.

To determine just what medium will most perfectly and comprehensively approach the ideal has enlisted the attention of all refrigerating experts and countless experiments have been made. Earlier researches covered a considerable number of porous and fibrous substances, but while an immense amount of data was collected, all more or less instructive, yet they have led to a narrowing down of the list of available materials to a relative few. This list is about as follows:

Cattle hair and cattle hair felt.
Mineral wool—loose and in board form.
Cork—granulated and in board form.
Vegetable fibres—such as flax, tow, straw, etc.
Sawdust and mill shavings.
Hollow tiles.
Paper and paper felts.

While quantities of the bulk substances such as mineral wool, granulated cork, sawdust, mill shavings, etc., are used, it is generally due to some consideration other than insulating efficiency alone, for they are very indifferent insulators when all the factors of intrinsic value are considered. They have had their vogue and are rapidly giving place to self contained, or unit materials so to speak, which can be handled in sheets, or in board form, and more effectively applied. If rammed

TABLE VI.

ONE-HALF INCH HAIR FELT.

BETWEEN TWO LAYERS PAPER.

OBSERVED RESULTS.

DATE	Hour Ending	Average Temperature on Inside of Panel	Average Temperature on Outside of Panel	Weight of Ice Melted per Hour Pounds	REMARKS
I	II	III	IV	V	
Jan. 31	10:00	49.5	89.0	1.94	Ice Chamber filled 3:00 P. M. Jan. 30 and refilled 7:00 A. M. Jan. 31.
"	11:00	49.5	89.0	2.00	
"	12:00	49.5	88.8	1.93	
"	1:00	49.5	89.0	2.00	
"	2:00	49.5	88.9	2.00	
"	3:00	49.5	88.9	2.00	
"	4:00	49.5	89.0	1.93	
Feb. 1	10:00	49.5	89.0	1.90	Ice Chamber refilled 7:00 A. M.
"	11:00	49.5	89.4	1.90	
"	12:00	49.5	89.6	1.94	Test Observations
"	1:00	49.5	89.3	1.88	
"	2:00	49.5	89.3	1.90	
"	3:00	49.5	89.3	1.94	
"	4:00	49.5	89.5	1.88	
TOTAL - -		346.5	625.4	13.34	
AVERAGE -		49.5	89.3	1.906	

tight enough to prevent settling, the bulk materials become too dense to contain the needful amount of entrapped air. Again, they do not provide the changes of density found necessary to give the maximum of insulation within the minimum of space. For these reasons it is only the self contained or unit form of insulation which is worth considering, as embodying most completely the scientific principles of insulation. In this respect, the loose bulk materials bear the same relation to modern up-to-date unit forms of insulators, as the old obsolete mud pipe-coverings would to the present type of manufactured productions. This superiority needs no demonstration to-day, as it is universally recognized.

The question of the relative values of the newer mediums, however, is still an open one, occasioning more or less difference of opinion among the well-informed, and a corresponding confusion among the uninitiated. To further scientific knowledge, and to determine once for all the exact relative values of the most popular forms of manufactured insulators, the writer was commissioned by important interests to undertake a series of tests. A careful canvas of the field resulted in the selection of the following materials:

"Keystone" Hair Insulator.
"Linofelt" Flax Insulator.
Cork Board Insulator.
"Lith" Board Insulator.

The first two are of a certain comparable type, the last two are of another. As they all represent the "last word" in manufactured insulators it was not deemed necessary to go farther afield.

The intention was to establish a standard rating, one so accurate that it could be accepted by laboratories the world over. In conformity with this idea, it was a sine qua non that the work should be carried on under the best obtainable auspices—where the results would be given without fear or favor by a recognized authority beyond the possibility of any undue influence.

TABLE VII.

TWO INCH LITH.

OBSERVED DATA.

DATE	Hour Ending	Average Temperature on Inside of Panel	Average Temperature on Outside of Panel	Weight of Ice Melted Per Hour	REMARKS
I	II	III	IV	V	
Mar. 1	10:00	48	90	1.87	Ice Chamber filled 4:00 P. M. Feb. 28 and refilled 6:30 A. M. Mar. 1.
"	11:00	48	91	1.88	
"	12:00	48	90.5	2.00	
"	1:00	48	90	1.94	
"	2:00	48	90	1.87	
"	3:00	48	90	1.87	
"	4:00	48	90.5	1.88	
Mar. 2	10 00	48	90.5	1.94	Ice Chamber refilled 7:00 A. M.
"	11:00	48	90.5	1.88	
"	12:00	48	90.1	1.88	Test Observations
"	1:00	48	90.2	1.87	
"	2:00	48	90.6	1.87	
"	3:00	48	90.3	1.88	
"	4:00	48	90.7	1.87	
TOTAL - -		336	632.9	13.19	
AVERAGE -		48	90.4	1.884	

The selection of Purdue University was most happy from the fact that it is the official authority of the Associated Railway Master Mechanics of the United States, a body representing the largest industrial interest in this country, if not in the world. The Dean of the Engineering Faculty, Prof. W. F. M. Goss, gave the tests his personal supervision, which stands for a guarantee of accuracy.

After carefully examining every method heretofore employed in testing insulating materials, it was felt that there was no apparatus extant sufficiently perfect to perform the functions indicated. Under the circumstances, Prof. Goss designed one on new and original lines. This calorimeter, as it is appropriately called, is simple and yet of a character so efficient as to mark a decided step in advance of anything hitherto employed for the purpose.

In testing insulating materials, the device generally used has consisted of a refrigerator, the walls of which were insulated with the material to be tested. When the test was finished, the refrigerator had to be taken apart and rebuilt with another material to be tested. It was almost impossible to make sure that the refrigerator would be rebuilt with the same nicety and care as in the original case, that all the joints would be as tight in the second test as in the first, or that all conditions could be repeated.

In such an apparatus it was always necessary to carry an unknown and unmeasurable amount of heat-transmission through the apparatus itself. That designed by Prof. Goss, however, permitted the testing of each material in turn without altering the apparatus in any way. This gave a control which insured like conditions in all tests. It was of such design as to make it possible to measure the average heat-transmission through every square foot of surface of tested material. An additional feature is that transmission outside of the area of tested materials, i.e., of exposed parts of the apparatus itself, could be accurately measured so that reports herewith submitted have been corrected and therefore represent true results.

Description of Apparatus Employed.

The apparatus employed consists of an enclosed calorimeter, the walls of which were constructed of the materials to be tested. In anticipation of a test the interior of the calorimeter was charged with ice, which was melted by heat passing the insulating materials surrounding it. The quantity of heat thus transmitted by the materials under test was determined by the weight of ice melted.

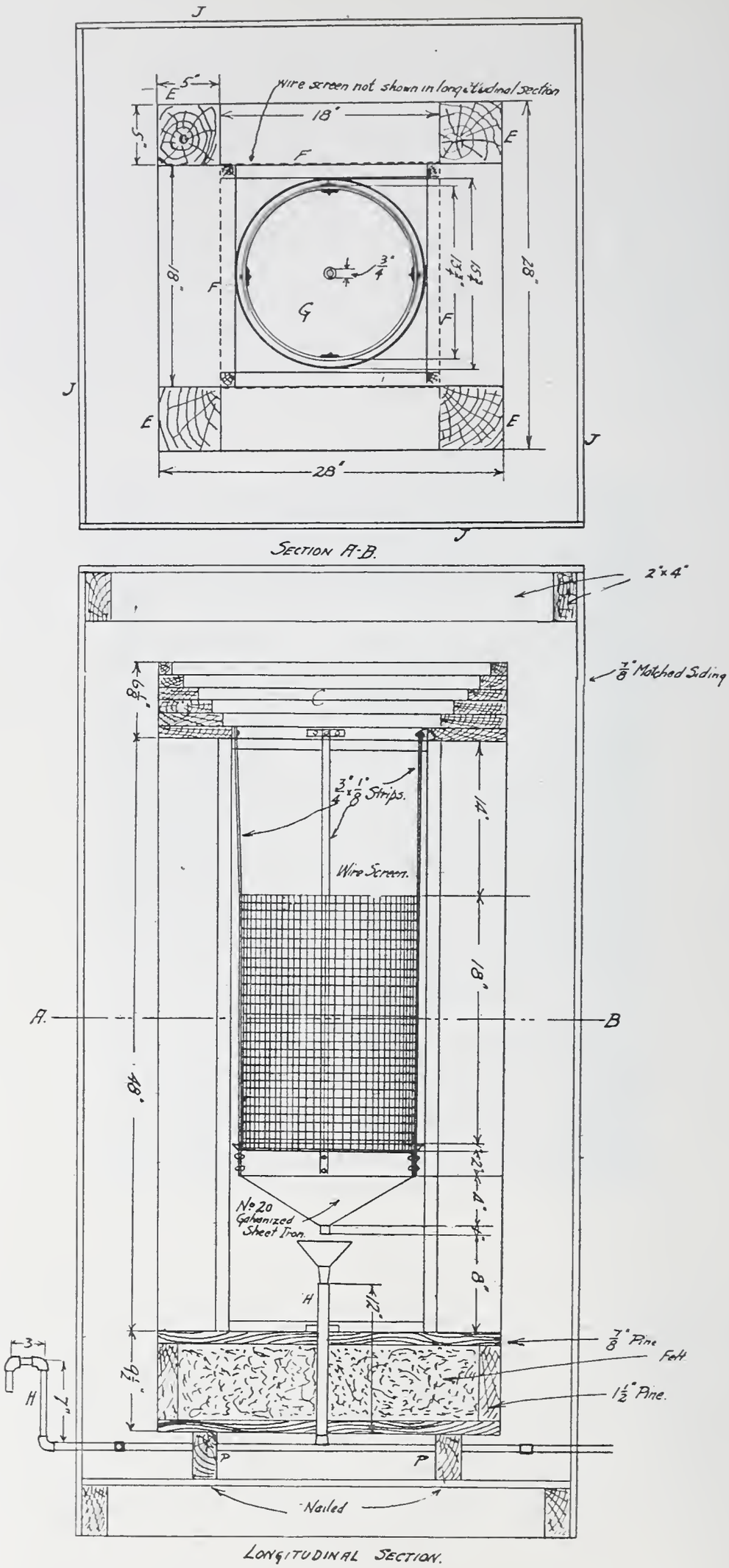
Figure 1.

The design of the apparatus is shown by Figs. 1, 2 and 3, its general appearance before the application of the insulating material by Fig. 1, and its appearance with the insulating material in place by figure 2. Referring to Fig. 3, it will be seen that the calorimeter chamber is rectangular in form, and may be described in detail as follows:

The bottom (D) approximately 28 inches square, is cellular in form tightly packed with hair felt. The top (C) is of wood construction of such form as to receive a series of covers. The covers consist of plates of sheet iron to the under side of which is secured a half layer of hair felt. There is one cover for each step in the top (C) and the seal between each cover and its support is made secure by the interposition of the hair felt between the step and the plate.

FIGURE 2.

Between the bottom (D) and the top (C) (Fig. 3) extend four posts (E E E E) and across the inner face of these are arranged four panels of wire netting. The manner of application and the appearance of the wire nettting are shown by Figs. 3 and 1 respectively. By its construction four panels are formed, each approximately 18 inches wide and 48 inches high. As thus far described, these panels consist only of


Wire screen not shown in longitudinal section
SECTION A-B.
2"x4"
7/8" Matched Siding
3/4"x1/8" Strips.
Wire Screen.
No 20 Galvanized Sheet Iron.
7/8" Pine
Felt
1 1/2" Pine.
Nailed
LONGITUDINAL SECTION.

(554) FIGURE 3.

wire netting, but in the use of the apparatus each panel is carefully covered with the material to be tested, which is pressed against the wire netting and carefully fitted to the frame at the edges being sealed at these points either by the use of a light quarter-round, or by the use of some plastic material. The exterior appearance of a panel of material thus arranged for test is well shown by Fig. 2. In this figure, the joint between the material and frame is shown at M N, the letter M being upon the panel under test and the letter N. upon one of the corner posts constituting part of the frame.

Within the calorimeter and accessible from the top, is arranged a cylindrical ice chamber (G) which, in common with the rectangular panels, is composed of 3/8 inch mesh galvanized wire netting. Below this, a funnel-shaped collector supported the ice and collects the drip which passes to the pipe (H) hence through the bottom of the calorimeter and through the outside wall of the enveloping jacket, at which point drip may be collected. The flat surface constituting the bottom of the calorimeter is constructed of wood, and is heavily sealed and coated with paraffine. During tests no signs of moisture appeared upon any part of the interior of the calorimeter, excepting that in contact with the ice or water.

For the purpose of cutting off chance drafts and to insure uniform exposure of the materials under test, the whole calorimeter was enveloped in a case (J) Fig. 1 constructed of 7/8 inch matched flooring and lined on the inside with asbestos paper. Access to the panels of the calorimeter was secured through doors (K) in each of the four sides of the enveloping jacket, a steam coil (P) between the jacket and the calorimeter served to slightly increase the temperature to which the calorimeter was exposed and was a means by which this temperature could be controlled. The gage (Q) Fig 1 connects with this pipe. The fact should be noted that this enveloping jacket, which in Figs. 1 and 2 constitutes the most conspicuous part of the apparatus, is not involved in

TABLE VIII.

ONE LAYER.

TWO INCH CORK BOARD.

OBSERVED RESULTS.

DATE	Hour Ending	Average Temperature on Inside of Panel	Average Temperature on Outside of Panel	Weight of Ice Melted Per Hour Pounds	REMARKS
I	II	III	IV	V	
Dec. 3	10:15	50.3	89.5	2.78	Ice Chamber filled 3:00 P. M. Dec. 2 and refilled 6:45 A. M. Dec. 3.
"	11:15	50.3	88.5	2.75	
"	12:15	50.3	89.0	2.63	
"	1:15	50.3	89.5	2.63	
"	2:15	50.3	89.5	2.69	
"	3:15	50.3	89.5	2.63	
"	4:15	50.3	89.5	2.63	
Dec. 5	10:30	50.3	88.2	2.50	Ice Chamber refilled 7:30 A. M. Dec. 2 and refilled 6.45 A. M. Dec. 3. Test Observations
"	11:30	50.3	90.7	2.66	
"	12:30	50.3	89.5	2.63	
"	1:30	50.3	89.5	2.57	
"	2:30	50.3	89.0	2.50	
"	3:30	50.3	90.0	2.57	
"	4:30	50.3	89.5	2.50	
TOTAL - -		352.1	626.4	17.93	
AVERAGE - -		50.3	89.5	2.56	

the measurements which were taken. It has no other part to perform than that of a screen for the calorimeter.

Methods Employed.

The insulating material to be tested was carefully applied to the four panels of the calorimeter, great care being taken, as already described, to make a secure seal between the material to be tested and the calorimeter. This accomplished, the several covers were removed from the top of the calorimeter and about 85 pounds of ice, broken in small lumps, was placed in the ice chamber. The covers were then replaced and the drip from the melting of the ice was caught in a large bottle (L) Fig. 1, having a neck sufficiently small to prevent perceptible loss by evaporation. Meanwhile, the pressure in the heating coil was regulated to maintain a temperature of about 90 degrees within the enveloping jacket, which temperature, and that on the inside of the panel, was measured by the use of standard thermometers placed in close proximity to the surface of the material under test.

After a considerable period, usually about twenty-four hours during which time the various parts of the calorimeter and the materials were assumed to be tending toward a fixed condition of temperature, the covers were again removed and a new charge of ice supplied. After this, observations were taken at regular intervals and recorded. When, judging from the observations, it appeared that the ice was melting at a uniform rate, the test was assumed to have begun. The test observations were usually continued for a period of seven hours. The latent heat of the ice was taken at 144 thermal units, which value was used in determining the number of thermal units transmitted by the calorimeter. Logs of the test which will assist in defining the process, appear as Tables 1 to 9 inclusive.

TABLE IX.

TWO INCH CORK BOARD.

OBSERVED DATA.

DATE	Hour Ending	Average Temperature on Inside of Panel	Average Temperature on Outside of Panel	Weight of Ice Melted Per Hour	REMARKS
I	II	III	IV	V	
Feb. 8	11:00	43.8	90.5	1.03	Ice Chamber filled 3:00 P. M. Feb. 7 and refilled 8:00 A. M. Feb. 8.
"	12:00	43.8	90.2	1.06	
"	1:00	43 8	90.0	1.09	
"	2:00	43.8	90.9	1.16	
"	3:00	43.8	90.3	1.25	
"	4:00	43.8	90.2	1.22	
"	5:00	43.8	90.8	1.19	
Feb. 9	10:30	43.8	90.8	1.25	Ice Chamber refilled 7:00 A. M.
"	11:30	43.8	90.6	1.28	
"	12:30	43.8	90.5	1.25	Test Observations
"	1:30	43.8	90.3	1.25	
"	2:30	43.8	91.0	1.25	
"	3:30	43.8	91.0	1.31	
"	4:30	43.8	90.8	1.25	
TOTAL - - -		306.6	635.0	8.84	
AVERAGE - -		43.8	90.7	1.263	

Calibration Test.

The method thus described provides for the collection and weighing of all water resulting from the melting of the ice, also, that the heat which melts the ice be transmitted to the inside of the calorimeter through the panels of the materials under test and also in part through the base and through the top. That this might be determined, a calibration test was made the results of which are given in Table 14.

In preparation for this test, the four panels were filled with a construction similar to that employed in the top, that is, each panel was filled with alternating layers of ½ inch hair felt and sheet iron, there being seven layers of each. This arrangement made all surfaces of the calorimeter of the same construction.

From results obtained under these conditions, it was possible to determine the amount of heat transmitted per unit area for the whole calorimeter, for which, and the known area of the top and bottom, the amount transmitted by these latter surfaces could be calculated. Since throughout the tests there was no change in the construction of the top and bottom, it has been assumed that the heat which was found to be transmitted through them in the calibration test was equal to that transmitted in each of the other tests, and corrections have been made accordingly.

Constants:—

Number of panels 4
Size of panels .....18.06 in. by 48.18 in.
Area of four panels .....24.12 sq ft.
Area of top and bottom .....4.53 sq. ft.
Thermal units transmitted .....
.....144 by pounds of water collected.
Weight of ice melted per degree difference of temperature per hour as a result of radiation through top and bottom as determined by calibration test .... .00205 lbs.

TABLE X.

WALL COMBINATION No. 1.

OBSERVED DATA.

DATE	Hour Ending	Average Temperature on Inside of Panel	Average Temperature on Outside of Panel	Weight of Ice Melted per Hour Pounds	REMARKS
I	II	III	IV	V	
Dec. 10	10:15	47.9	91.5	1.47	Ice Chamber filled 6:45 A. M.
"	11:15	47.9	94.0	1.34	
"	12:15	47.9	92.0	1.45	
"	1:15	47.9	92.0	1.41	
"	2:15	47.9	92.0	1.42	
"	3:15	47.9	91.5	1.38	
"	4:15	47.9	91.5	1.36	
Dec. 12	10:15	47.9	90.5	1.25	Ice Chamber refilled 2:00 P. M. Dec. 11 and 6:30 A. M. Dec. 12. Test Observations
"	11:15	47.9	90.8	1.25	
"	12:15	47.9	91.8	1.28	
"	1:15	47.9	91.5	1.28	
"	2:15	47.9	91.0	1.28	
"	3:15	47.9	91.0	1.28	
"	4:15	47.9	91.2	1.28	
Total	- -	335.3	637.8	8.90	
Average	-	47.9	91.1	1.27	

Description of the Materials Tested.

The materials tested may be described as follows:

Arctic Keystone—This consists of a layer of hair between two layers of waterproof paper, the whole construction being stitched through with coarse thread along straight lines approximately 8 inches apart. The nominal thickness of this material as tested is ½ inch, weight .478 pounds per square foot.

Linofelt—This is designated as flax filled insulating material. It consists of a rather loosely packed fibrous layer of flax hemp between two sheets of waterproof paper stitched in a manner similar to that employed in the Arctic Keystone. The nominal thickness of the sample tested is ½ inch, weight .420 pounds per square foot.

Cork Board—This is made up of particles of cork of irregular proportions from ⅜ to ¼ inch in size. These present the appearance of having been thoroughly coated with asphaltum and afterwards molded under pressure into boards of the form described. Those tested were of two sizes, namely, 10 in. by 36 in. and 12 in. by 36 in. The thickness of the board is 2 inches, weight 3.5 pounds per square foot.

"Lith" board—This is molded board said to be composed of a mixture of flax fibre, mineral wool and some adhesive substance, possibly silicate of soda. The thickness of the material as tested is 2 inches, weight 2.9 pounds per square foot.

In addition to the tests of simple materials, as above described, others were made involving the combination of

TABLE XI.

WALL COMBINATION NO. 2.

OBSERVED RESULTS.

DATE	Hour Ending	Average Temperature on Inside of Panel	Average Temperature on Outside of Panel	Weight of Ice Melted per Hour. Pounds	REMARKS
I	II	III	IV	V	
Dec. 19	10:30	42.3	92.5	.91	Ice Chamber filled 9:00 A. M. Dec. 18 and refilled 7:30 A. M. Dec. 19.
"	11:30	42.3	93.0	.87	
"	12:30	42.3	92.5	.87	
"	1:30	42.3	91.5	.91	
"	2:30	42.3	91.0	.97	
"	3:30	42.3	90.5	.97	
"	4:30	42.3	90.5	.97	
Dec. 20	10:15	42.3	91.0	1.03	Ice Chamber refilled 6:30 A. M.
"	11:15	42.3	91.0	1.00	
"	12:15	42.3	92.5	1.03	Test Observations
"	1:15	42.3	93.0	1.03	
"	2:15	42.3	92.5	1.03	
"	3:15	42.3	92.5	1.03	
"	4:15	42.3	91.0	1.03	
Total - -		296.1	643.5	7.18	
Average -		42.3	91.9	1.03	

such materials, sections of which appear as Figs. 5 to 9, inclusive. A complete statement of all tests is as follows:

1. One layer Arctic Keystone.
2. Two layers Arctic Keystone.
3. One layer Linofelt.
4. Two layers Linofelt.
5. One layer ½ inch Hair felt.
6. One layer ½ inch Hair felt between two layers of paper.
7. One layer of 2-inch "Lith."
8. One layer of 2-inch Cork board.
9. Seven layers of hair felt alternating with seven layers of sheet iron (Calibration test).
10. Wall Combination No. 1 (Fig. 5.)
11. Wall Combination No. 2 (Fig. 6.)
12. Wall Combination No. 3 (Fig. 7.)
13. Wall Combination No. 4 (Fig. 8.)
14. Wall Combination No. 5 (Fig. 9.)

Results of Tests.

Tables 1 to 14 inclusive are logs of the tests. They illustrate the method of conducting the tests and their summary of results forms the data of Tables 15, 16 and 17. These last three tables are explained as follows:

Table 15 presents a summary of observed results including the temperature outside of the calorimeter, which is that to which the insulating material is exposed, the temperature inside of the calorimeter, which for points near the panel was found to be always greater than that of melting ice, and the total weight of ice melted for the period of the test. A comparison of the results of Columns I and II. of this table will indicate the degree of uniformity which prevailed throughout the series.

Table 16 is a summary of the performance of the different materials in terms of pounds of ice melted. Column IV

TABLE XII.

WALL COMBINATION No. 3.

OBSERVED DATA.

DATE	Hour Ending	Average Temperature on Inside of Panel	Average Temperature on Outside of Panel	Weight of Ice Melted Per Hour Pounds	REMARKS
I	II	III	IV	V	
Mar. 1	11:00	38.8	90.8	1.43	Ice Chamber filled 8:00 A. M.
"	12:00	38.8	90.5	1.31	
"	1:00	38.8	90.5	1.12	
"	2:00	38.8	91.5	1.06	
"	3:00	38.8	91.5	1.00	
"	4:00	38.8	91.4	.97	
"	5:00	38.8	91.0	.86	
Mar. 2	11:00	38.8	92.0	.81	Ice Chamber filled 8:00 A. M.
"	12:00	38.8	93.9	.84	
"	1:00	38.8	93.0	.84	
"	2:00	38.8	92.0	.84	Test Observations
"	3:00	38.8	91.5	.84	
"	4:00	38.8	91.5	.81	
"	5:00	38.8	91.8	.84	
TOTAL - -		27.16	645.7	5.82	
AVERAGE -		38.8	92.2	.83	

of this table presents values which are reduced to a common basis. Any comparison which may be made involving these values will give a correct measure of the relative insulating qualities of the materials to which they belong.

Table 17 shows transmission of heat by the several materials expressed in terms of thermal units. Column IV presents the percentage of increase (+), or decrease (—), for each material as compared with one layer of Arctic Keystone which is assumed to be zero.

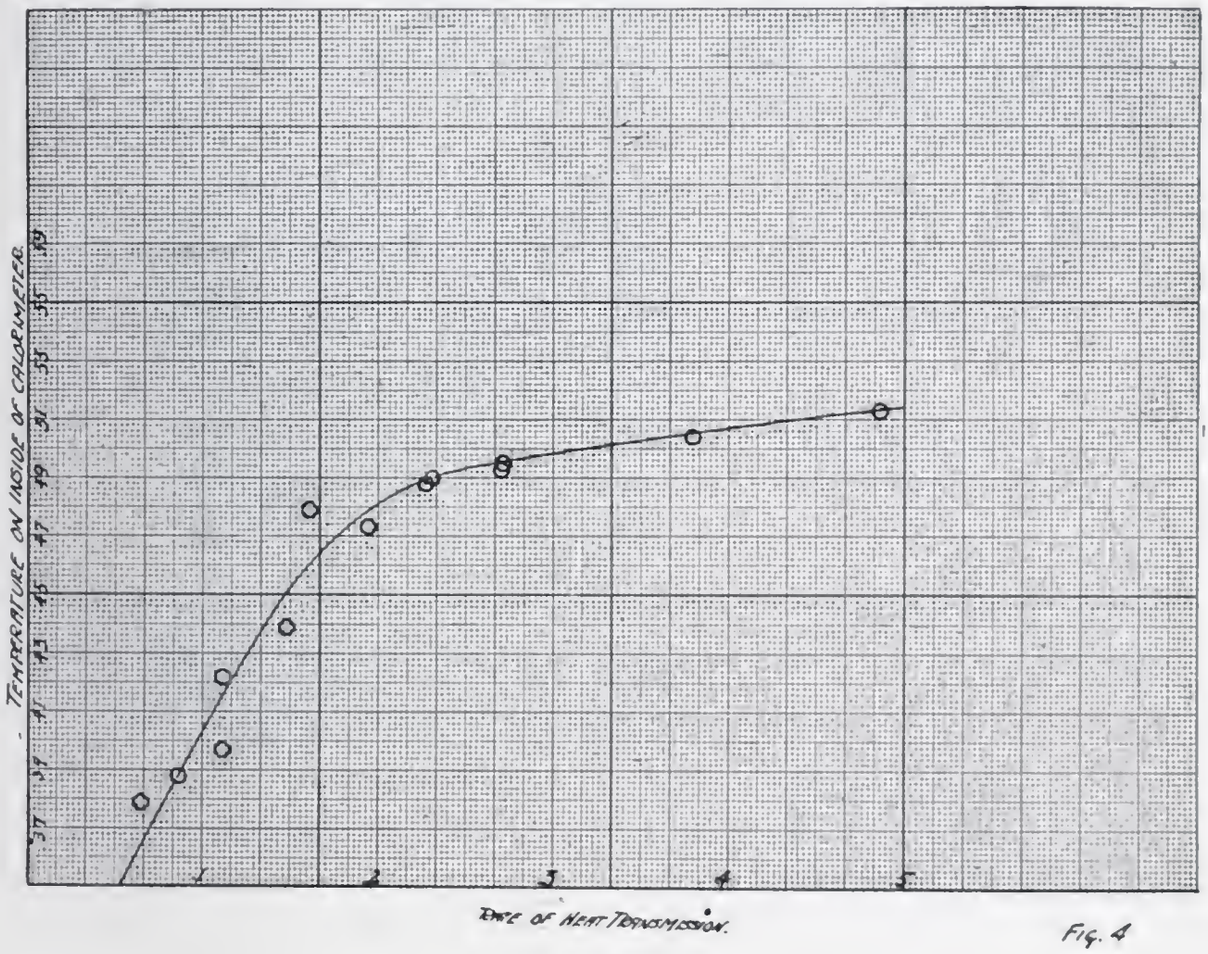


FIGURE 4.

A matter of practical as well as of scientific value which has been developed by the tests is set forth by Fig. 4. This shows the relation between the temperature of the inside of the calorimeter, and the rate at which the heat is passing through the insulating material. The diagram makes evident the fact that as the rate of heat transmission is reduced, the temperature within the calorimeter is lowered. In other

TABLE XIII.

WALL COMBINATION No. 4.

OBSERVED RESULTS.

DATE	Hour Ending	Average Temperature on Inside of Panel	Average Temperature on Outside of Panel	Weight of Ice Melted per Hour Pounds	REMARKS
I	II	III	IV	V	
Jan. 5	10:30	39.7	90.4	1.03	Ice Chamber filled 9:00 A. M. Jan. 4 and refilled 7:45 A. M. Jan. 5.
"	11:30	39.7	90.6	1.06	
"	12:30	39.7	91.0	1.00	
"	1:30	39.7	91.5	1.00	
"	2:30	39.7	91.2	1.03	
"	3:30	39.7	91.5	1.06	
"	4:30	39.7	91.2	1.06	
Jan. 6	10:30	39.7	90.9	1.09	Ice Chamber refilled 8:00 A. M.
"	11:30	39.7	91.1	1.09	
"	12:30	39.7	91.5	1.12	Test Observations
"	1:30	39.7	91.5	1.12	
"	2:30	39.7	91.2	1.12	
"	3:30	39.7	91.0	1.12	
"	4:30	39.7	91.0	1.09	
TOTAL - -		277.9	638.2	7.75	
AVERAGE -		39.7	91.2	1.107	

words, efficiency in insulation means not only a saving in ice but the maintenance of a lower temperature. The figures obtained show that while the temperature of exposure is practically the same, the temperature of the refrigerating space may be several degrees lower with one material as the insulating medium than with another.

Determination of Results From the Foregoing.

It is apparent that the insulator filled with loose, unfelted hair stands supreme among the materials tested in resistance to heat-transmission. This being clearly demonstrated, it

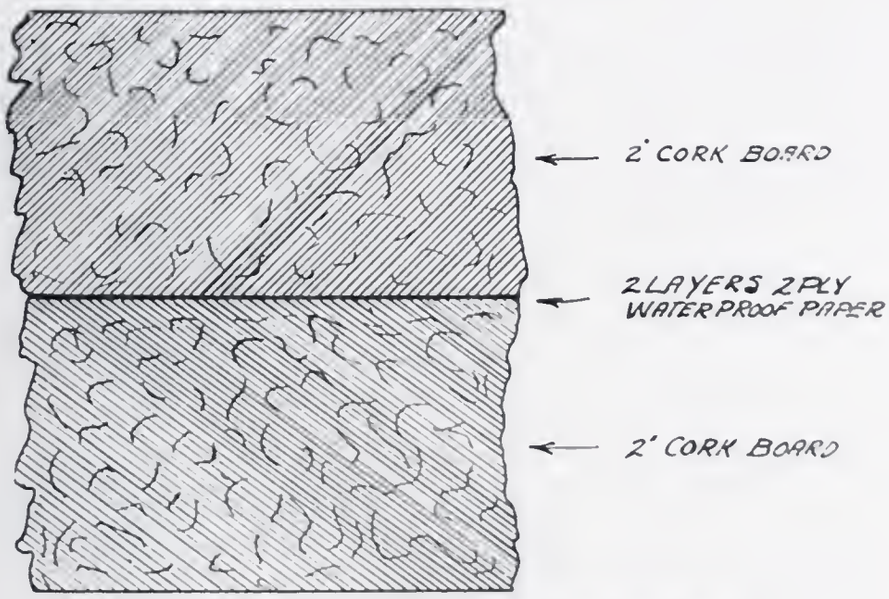


Figure 9—Wall Combination No. 5.

was decided to test it further in combination with boards, as it is commercially used for cold-storage walls, and thus secure data of wall-values on a practical basis.

As the manufacturers recommend that two different thicknesses of "Keystone" be combined, the ½ inch thick "Arctic" between two layers of the ¼ inch thick "Neptune" were used as a unit of insulation in the wall construction and tests were made accordingly. Figs. 5, 6 and 7 illustrate these constructions, known respectively as Wall Combinations No.'s 1, 2 and 3. Results are given in Tables 10, 11 and 12.

TABLE XIV.

CALIBRATION TEST.

OBSERVED RESULTS.

DATE	Hour Ending	Average Temperature on Inside of Panel	Average Temperature on Outside of Panel	Weight of Ice Melted Per Hour Pounds	REMARKS
I	II	III	IV	V	
Jan. 12	10:30	37.9	90.0	.75	Ice Chamber filled 4:00 P. M. Jan. 11 and refilled 8:00 A. M. Jan. 12.
"	11:30	37.9	90.2	.78	
"	12:30	37.9	90.2	.75	
"	1:30	37.9	90.3	.62	
"	2:30	37.9	90.7	.69	
"	3:30	37.9	91.1	.69	
"	4:30	37.9	90.9	.69	
Jan. 13	10:30	37.9	91.0	.69	Ice Chamber refilled 8:00 A. M.
"	11:30	37.9	91.4	.69	
"	12:30	37.9	91.0	.69	Test Observations
"	1:30	37.9	91.0	.69	
"	2:30	37.9	91.0	.69	
"	3:30	37.9	90.7	.72	
"	4:30	37.9	91.0	.69	
TOTAL - -		265.3	637.1	4.86	
AVERAGE -		37.9	91.0	.69	

In order to compare these forms of "Keystone" walls with some other popular constructions, and as "Cork Board" is more widely used than "Lith Board," tests were made of "Cork Board" in accordance with the usual specifications for this material, viz: two layers of 2 inch Cork Board with two layers of waterproof paper between and called Wall Combination No. 5. See Figure 9 and Tables 15, 16 and 17.

The result of these special tests confirmed the first determination as to the superiority of Keystone Hair Insulator. In order to show the ratings of all the materials and combinations of materials tested a study of Table 18 is suggested.

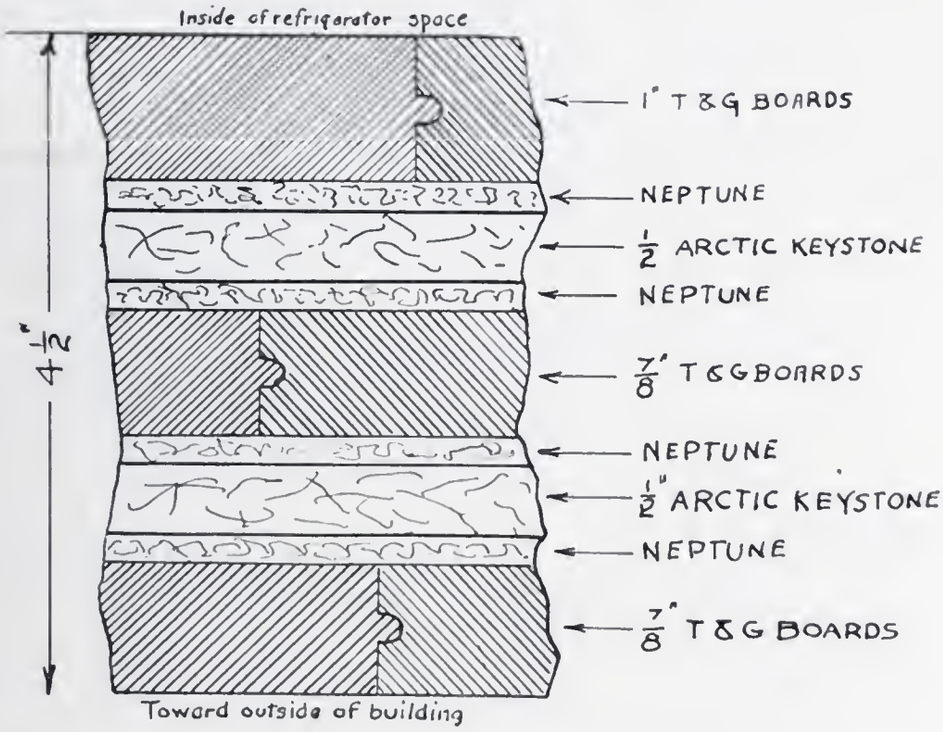


FIGURE 6—WALL COMBINATION NO. 2.

Table 18 shows the relative insulating value of the several materials and combinations tested in terms of each of the different materials. The value of the material chosen as the basis in each column is arbitrarily taken as unity. For example, in Column 1, Arctic "Keystone" (two layers) is taken as unity (1.000) while "Linofelt" (two layers) has .835, which means that as an insulating material "Linofelt" is worth only $\frac{8}{10}$ as much as Arctic "Keystone." Attention is called to the fact that the value of this table may be used

primarily to determine the relative saving in ice by the substitution of any one of the materials tested for another.

For those interested particularly in refrigerator cars, Table 19 will have especial interest.

If anything is clearly demonstrated by the tests, it is all in the way of proving the correctness of the principles made plain in this paper. Take for example the two tests of hair felt, one of the felt alone, and the other in which the felt was covered on each side with paper. It is conclusively shown that the addition of the paper covering increased the resistance of heat-transmission nearly 100 per cent.

TABLE XV.

SUMMARY.

OBSERVED RESULTS.

INSULATING MATERIAL	Average Temperature Outside of Panel	Average Temperature Inside of Panel	Total Weight of Ice Melted during 7 hours Pounds
	I	II	III
Arctic Keystone, one layer	89.6	49.0	11.61
Arctic Keystone, two layers	89.3	47.3	10.05
Linofelt, one layer	90.9	49.3	*15.98
Linofelt, two layers	89.1	48.8	11.44
½″ Hair felt, one layer	89.5	51.3	22.42
½″ Hair felt between two layers of paper	89.3	49.5	13.34
2″ Lith, one layer	90.4	48.0	13.19
2″ Cork board, one layer	89.5	50.3	17.93
Wall Combination No. 1	91.1	47.9	8.90
Wall Combination No. 2	91.9	42.3	7.18
Wall Combination No. 3	92.2	38.8	5.82
Wall Combination No. 4	91.2	39.7	7.75
Wall Combination No. 5	90.7	43.8	8.84

* Eight hour test.

This difference was doubtless due less to the added value of the paper as an insulating unit, than to its sealing up the air enmeshed in the hair fibres of the felt. The paper prevented the air from circulating and the loss by convection which occurred when the paper was omitted.

Again, compare felted hair with hair unfelted. In the former the hair weighs 6¼ oz. and in the latter it weighs

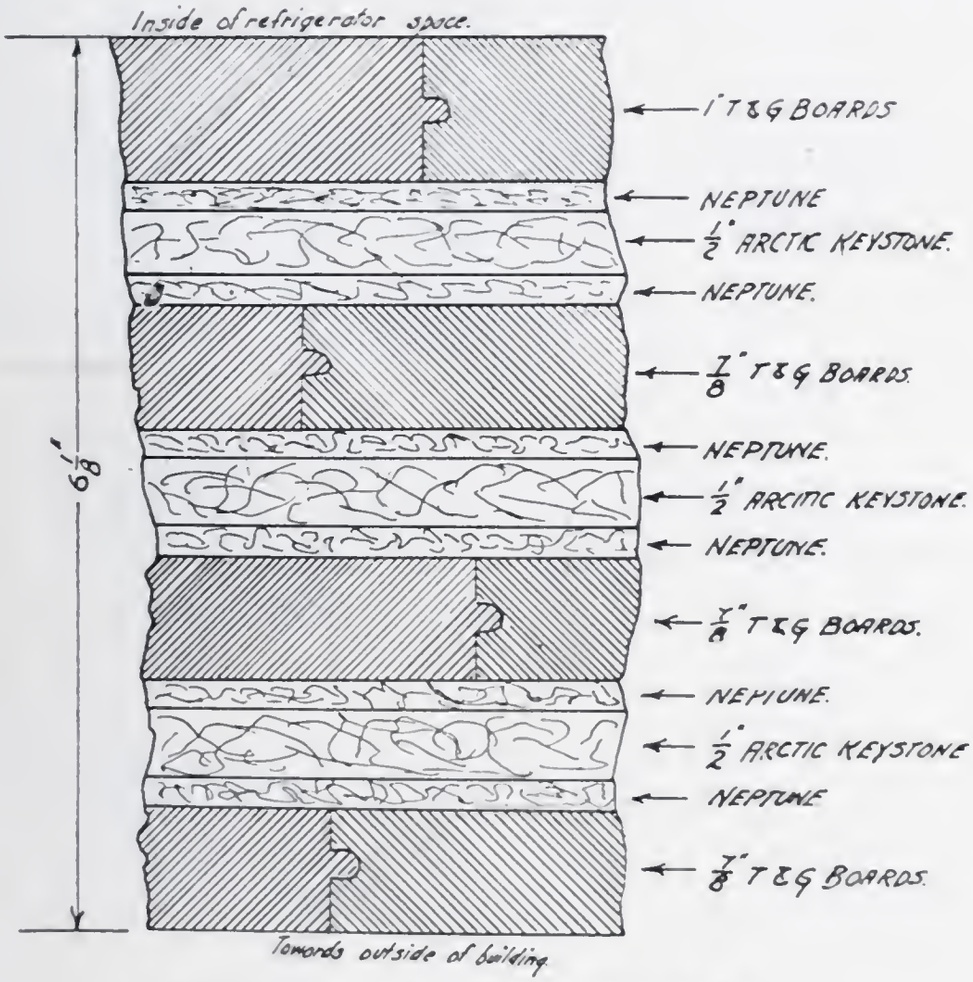


FIGURE 7—WALL COMBINATION NO. 3.

4¼ oz. per square foot, yet the felt with the same kind of paper on each side, measures in insulating value .825 against 1.000 for hair unfelted (See Table 18). What does this demonstrate? Simply that the compacting of the hair fibres necessary to bring them into felting relations expels enough air to reduce the insulating value of the hair accordingly.

Could anything more firmly establish the theory as to the value of confined or "dead" air? In the case of the felted

hair we illustrate a factor of heat-transmission additional to convection, viz: conduction. By bringing the fibres into felting relation, we have forced them into such close contact that their conductivity was necessarily increased, just how

TABLE XVI.

ICE MELTED PER TWENTY-FOUR HOURS.

INSULATING MATERIAL.	Difference of Temperature between Inside and Outside of Calorimeter.	Average Weight of Ice Melted per Hour, Pounds.	Equivalent Weight of Ice Melted per 100 Square Feet of Radiating Surface, per 24 Hours, under the Conditions of the Test. Pounds.	Equivalent Weight of Ice Melted per 100 Square Feet of Radiating Surface per Degree Difference of Temperature, per 24 Hrs. Pounds
	I.	II.	III.	IV.
Arctic Keystone, one layer, .	40.6	1.576	156.82	3.862
Arctic Keystone, two layers,	42.0	1.349	134.29	3.196
Linofelt, one layer, ...	41.6	1.912	190.25	4,572
Linofelt, two layers, . . .	40.3	1.551	154.33	3.829
½″ Hair Felt, one layer, . .	38.2	3.125	310.94	8.140
½″ Hair Felt between 2 layers of paper	39.8	1.814	180.50	4.535
2″ Lith, one layer, ...	42.4	1.797	178.81	4.217
2″ Cork Board, one layer. . .	39.2	2.481	246.87	6.298
Wall Combination, No. 1, . .	43.2	1.183	117.71	2.725
Wall Combination, No. 2, . .	49.5	.925	92.04	1.859
Wall Combination, No. 3, . .	53.4	.722	71.84	1.345
Wall Combination, No. 4, . .	51.5	1.002	99.70	1.936
Wall Combination, No. 5, . .	46.9	1.167	116.09	2.475

much is not determined. Hair being a negative substance composed of a series of layers of spongy material, we assume it to be naturally a poorer conductor than a vegetable fibre which contains more or less mineral elements. While this

would indicate hair as an ideal fibre, yet it will conduct some heat under conditions of close contact.

There is more insulation per square foot in ½ inch "Keystone" than in ½ inch hair felt, yet there are conditions wherein the latter is safer to use because it more readily adapts itself to structural requirements, or meets in a better way the necessities of a particular use. For several kinds of refrigerator cars as now constructed it stands in a class of its own.

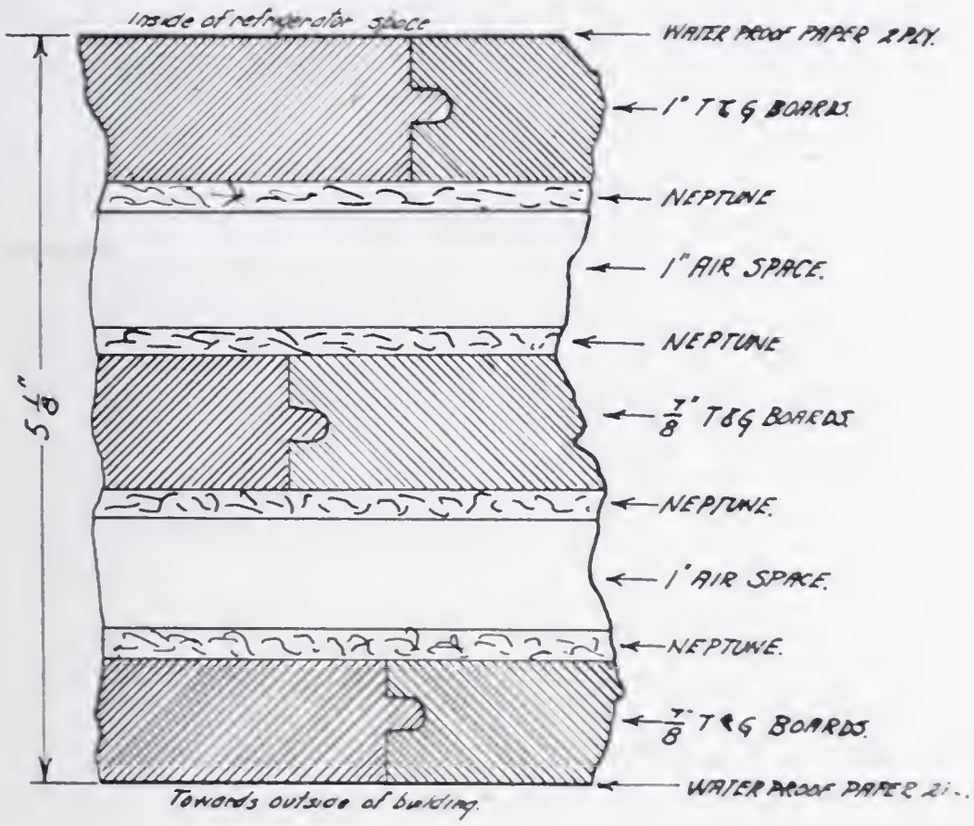


FIGURE 8—WALL COMBINATION NO. 4.

There are other conditions where several of the materials tested could be advantageously combined. To do this, however, requires a broader-minded policy on the part of experts than is commonly known to-day. The expert often adopts a certain material or form of construction, and sticks to it through thick and thin regardless of consequences or the saving that might be effected.

We have seen the value of paper for confining air within the body of the enclosed insulating medium. It also performs

another function of immense importance, i. e. to protect the insulating medium from dampness. To properly do this the paper should be of itself non absorbent.

TABLE XVII.

HEAT TRANSMISSION.

INSULATING MATERIAL	Heat (B. T. U.) Transmitted for each pound of Ice Melted	Total Heat (B. T. U.) Transmitted per hour, 21.12 square feet of Radiator Surface.	Equivalent Heat (B. T. U.) Transmitted per square foot of Radiating Surface. Per Difference of Temperature, Per Hour.	Per cent. of increase in heat transmission compared with that of one layer of Arctic Keystone. (Increase +, Decrease —)
	I	II	III	IV.
Arctic Keystone, one layer .	144	226.94	.2317	———
Arctic Keystone, two layers	144	194.26	.1918	—17.2
Linofelt, one layer . . .	144	275.33	.2743	+ 18.4
Linofelt, two layers . . .	144	223.34	.2297	— 0.9
½″ Hair Felt, one layer .	144	450.00	.4884	+110.8
½″ Hair Felt, between 2 layers of Paper	144	361.22	.2721	+ 17.4
2″ Lith, one layer	144	258.77	.2530	+ 9.4
2″ Cork Board, one layer .	144	357.26	.3778	+ 63.1
Wall Combination No. 1 .	144	170.35	.1635	— 29.4
Wall Combination No. 2 .	144	133.20	.1116	— 51.8
Wall Combination No. 3 .	144	103.97	.0807	— 65.2
Wall Combination No. 4 .	144	144.29	.1162	— 49.9
Wall Combination No. 5 .	144	168.05	.1485	— 35.9

Dry papers, so called, are unsafe as a class. While some of them may possess high insulating value they are mostly absorbent of moisture. When subjected to the moisture incidental to cold storage they take it up like a sponge and pass it to the medium they enclose.

Recognizing the necessity of excluding moisture, great care should be exercised in selecting a paper. Only such papers should be adopted as are made of stock least absorbent of moisture, this excludes the wood-pulp varieties. They should be saturated with a reliable waterproofing compound. This compound should not be volatile, neither should it become brittle with age.

The cost of a first class wall may be about 30c per square foot. Six layers of suitable paper will cost about 3c. An ordinary paper may cost $1.30 per M. less, saving about 20%. That is equal to 20% of 10% or 2% saving on the entire cost of insulation.

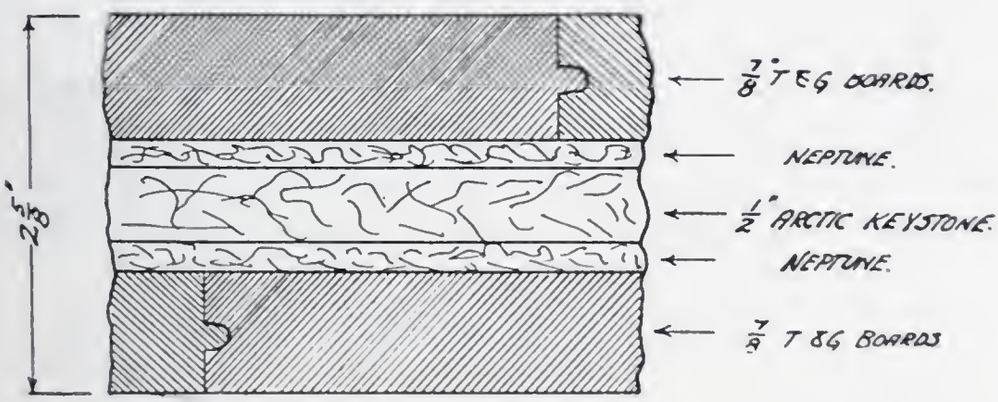


FIGURE 5—WALL COMBINATION NO. 1.

Liberal outlay for insulation permits economies elsewhere in the installation, a smaller expenditure for refrigerant, whether it is handled through pipes or carried in bunkers. Superior insulation will maintain equable temperatures and safeguard the chances of breakdowns or deterioration in the stored products. It is therefore the only true economy in the practical application of the principles of insulation to commercial use.

We have touched upon only one branch of a great subject. It would be a matter for congratulations if Engineering Societies gave more time to its consideration. That it is worth while there can be no reasonable doubt. If this paper will stimulate thought in this direction, it will have served a useful purpose.

TABLE XVIII.

RELATIVE VALUES.

Relative Insulating Values, the Basis of Comparison Being Unity.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.
Arctic Keystone, two layers, .	**1.000**	1.198	1.208	1.319	1.419	1.430	1.970	2.546	.421	.582	.606	.774	.852
Linofelt, two layers, . . .	8.35	**1.000**	1.009	1.101	1.185	1.194	1.645	2.126	.351	.488	.506	.647	.712
Arctic Keystone, one layer, .	8.28	.991	**1.000**	1.092	1.174	1.183	1.631	2.108	.348	.482	.501	.641	.706
2″ Lith, one layer, ...	7.58	.908	.916	**1.000**	1.075	1.084	1.493	1.930	.319	.441	.459	.587	.646
½″ Hair Felt, between 2 layers of paper	.705	.844	.852	.930	**1.000**	1.008	1.388	1.795	.297	.410	.427	.546	.601
Linofelt, one layer, ...	.699	.837	.845	.922	.992	**1.000**	1.377	1.781	.294	.407	.424	.541	.596
2″ Cork Board, one layer, . .	.508	.608	.613	.670	.720	.726	**1.000**	1.293	.214	.295	.308	.393	.432
½″ Hair Felt, one layer, . .	.393	.470	.474	.518	.557	.562	.774	**1.000**	.165	.229	.238	.304	.334
Wall Combination, No. 3, . .	2.377	2.846	2.871	3.135	3.372	3.399	4.682	6.052	**1.000**	1.383	1.440	1.841	2.026
Wall Combination, No. 2, . .	1.719	2.058	2.076	2.267	2.438	2.458	3.386	4.377	.723	**1.000**	1.041	1.331	1.465
Wall Combination, No. 4, . .	1.651	1.977	1.995	2.177	2.342	2.361	3.251	4.204	.695	.961	**1.000**	1.278	1.407
Wall Combination, No. 5, . .	1.291	1.547	1.560	1.704	1.832	1.847	2.544	3.289	.543	.752	.783	**1.000**	1.101
Wall Combination, No. 1, . .	1.173	1.405	1.417	1.547	1.664	1.678	2.311	2.987	.494	.683	.711	.983	**1.000**

TABLE XIX.

MONEY VALUES.

REFRIGERATOR CARS.

INSULATING MATERIAL	Daily saving effected by the use of the several insulating materials on a standard refrigerator car having a box surface of 1200 square feet in comparison with the results which would be obtained from the use of one layer of Linofelt. Difference of temperature equals 35 degrees.	
	Pounds of Ice	Dollars, Ice at $2.00 per Ton
	I	II
½ inch hair felt between two layers of paper	15.54	.015
Arctic Keystone, one layer . .	298.20	.30
Linofelt, two layers	312.16	.31
Arctic Keystone, two layers .	577.92	.58

DISCUSSION.

JOHN A. MCCONNELL, Member—There seems to be one or two of the primary components of insulation that are omitted, or taken for granted, that we should get before us in an effort to clearly understand the paper.

We naturally suppose that insulation is almost the only thing, but experience throughout a number of years has shown me that, in refrigeration insulation, the first thing to do is to exclude air. For if the air comes in contact with the cold surface, the chilling condenses the air and frees a portion of the water contained in it, and that water dampens the insulating material and destroys it. Any attempt at insulation for refrigeration purposes is nullified, unless you keep in mind from the very start, the necessity of excluding air from the cold surfaces. Next to that is the necessity for insulating those cold surfaces sufficiently to prevent the heat from entering, or, if I should reverse the figure, to prevent the cold from

coming to the surface, chilling the air and causing water of condensation at that point. I have found these the two principal points to be considered in insulation.

The author says that he starts in beyond the steam engine, or beyond the point that we have usually been accustomed to consider in heat insulation. I think that one of the troubles with refrigerating engineers has been in their assuming, that insulation in connection with refrigeration was a new problem. The fact is, it is exactly the problem that has been worked out in heat insulation, only the action is reversed. In heat insulation, as the covering of steam pipes and all kinds of heated bodies, our problem was to prevent the heat from getting out. In refrigeration insulation the operation is reversed, and the problem is to prevent the heat from getting in, and the insulating material that accomplishes this in one case under like circumstances will accomplish it in the other. There is, however, this difference which has led to the adoption of the four or five classes of material named here to-night, in refrigeration insulation you do not have to contend with the factor of destruction by heat. Hair, vegetable fibre, wool, or any other vegetable or animal fibre can be applied in refrigeration insulation without being destroyed by heat. As they are cheaper they are generally resorted to and are, all things considered, better than any of the mineral insulations for this purpose. I noted that the author says: "It has been stated by some authorities, that three-fourths of the refrigeration applied to cold storage rooms, is spent in removing the heat that leaks in through the walls." That looks to me as though the refrigerating engineers had been a little slow about recognizing the absolute necessity of good non-conductors to keep out the heat, and that if they had more quickly appealed to those experienced in heat insulation, that very large loss should have been more rapidly overcome.

The author seems to emphasize that the wall should be built of different materials. That is correct so far as it goes, but he should go a little farther and say different non-conducting materials. I can build a wall of different materials, and

then I can build another wall of one material, yet my wall of one material will have twenty times as much insulating power as my wall of different materials. So that it is not so much the building up of walls of different materials, as so arranging your materials as to cause as many breaks as possible, as many points where the air intervenes between.

I notice that in constructing the box the author took half inch hair felt, or half inch of his loose hair, "Keystone" he called it, and packed it between layers of sheet iron. I say to you after many years of experience with this kind of thing; By all means avoid sheet iron in all refrigerating insulation. It is bad for two reasons; First, because the iron is the very best conductor of heat, except copper, and two or three of the precious metals; Secondly, because the sheet iron is quickly eaten up by rust. I am disposed to believe, while I think the paper is in the main along the right lines, that the author is partial to one particular form of material and overestimates its value. There are many situations in which bulky material can still be used to advantage, and used to probably better advantage than the more costly material built up between layers of paper.

Another point I wish to call attention to; In one of the tests quoted, two layers of water proof felt and two layers of one inch air cells melted seven and three-quarter pounds of ice in seven hours, while four inches of cork boards melt 8.84 pounds, or more than one pound more in the seven hours than the two layers of one inch air cell. Looking at them together convinces me there is an error. Just the two layers of two inch cork are shown, making four inches in thickness, whereas the waterproof material is confined between three separate layers of one inch flooring. I have no doubt that the major portion of the result produced in that case, is produced by the three inches of wood and not by the two inches of air, because you take an inch of air without being broken in any way, and, owing to transferring of heat by convection, it is a very poor insulator.

Where we all come to at last, the touchstone of the whole matter, is the cost. In the dollars and cents column it is stated; That a car containing 1200 square feet lined with half inch thickness of hair felt, there is a saving of only fifteen pounds per day or one and one-half cents; With half inch thickness of Keystone, which is really the same thing, hair in the loose condition, there is a saving of 269 pounds or thirty cents. That is evidently a mistake, it is preposterous and impossible that a half inch lining of hair felt should prevent the melting of only fifteen pounds of ice a day, whereas a half inch of almost precisely the same material, except that it is in a loose state and with layers of paper, should prevent the melting of 269 pounds.

S. M. Kintner, Member—The electrical engineer is interested in the heat insulation problem, but from a somewhat different point of view. All electrical machines are insulated and all electrical machines have heat. With the insulation that the electrical engineer puts on, it is desired to keep an electric charge in and to permit the heat to pass out. He is thus confronted with a more difficult problem than either the steam engineer, who tries to keep heat in without anything else to bother with, or the refrigeration engineer who simply tries to keep the heat out. In addition, in higher voltage work the electrical engineer is liable to encounter a condition of a heat generation in the insulation itself, due to a reversal of static forces of electricity, generating heat locally in spots in the insulating material itself. In some of the very best electrical machines, with efficiencies as high as 98%, it is found necessary, on account of the 2% losses which manifest themselves as heat, to immerse these machines in tanks of mineral oil, so as to afford means of getting the heat from the insulating material rapidly enough to limit the temperature to a safe value. In addition to the immersion in oil, it is generally found necessary, in the larger sized machines, to employ pipe through which water is circulated, to get rid of the heat still more rapidly. In other types of machines, it is found necessary to blow air currents through to dissipate

the heat. So that the electrical engineer is confronted with this problem, and has occasion in the designing of insulation, to become more or less familiar with the different characteristics of materials as heat insulators.

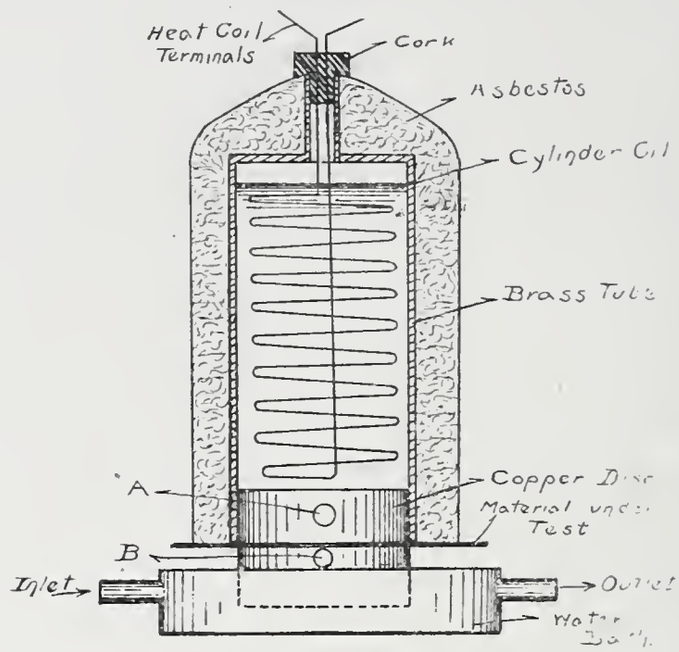
In listening to the paper of the evening there were several points that I noted as perhaps somewhat inaccurately stated: One statement I believe is a little incorrect, due no doubt to some ambiguous wording. He states that by the use of dissimilar materials better insulation is obtained, and he explains this by saying that at the junctions of these materials there is absorption of heat. I am sure he did not mean that at all, because it is evident that there is a heat current going through there, and no absorption at any place. The gradient of the heat potential at these different surfaces is changed it is true. I think Mr. McConnell has explained that point quite nicely when he stated that the difference in the heat gradient is due to the trapping of the air, and the difficulty with which heat is passed from the surface of a body to the air. I know in electrical machines that the temperature of the machines is always considerably higher than the surrounding air, while there is a film immediately in contact with the machine that is decidedly hotter than the film of air only a fraction of an inch away, and the gradient of this heat potential is quite abrupt at the surface.

Speaking of the necessity of maintaining insulation so as to prevent air currents, it may be of interest to note that 1425 cubic feet of air per minute changed in temperature one degree centigrade, will dissipate one horsepower.

There is a statement in the paper regarding the use of unlike materials, that I believe the author does not mean exactly what is stated. He advises strongly the use of dissimilar materials without stating that there is perhaps one particular kind of material, which if used in alternate layers with air spaces, would give a better heat insulation than would be obtained if that good material, and some other dissimilar materials were used without breaking up with air

spaces. Still air is the best heat insulator and any device that gives the most of it is the best heat insulator.

Regarding the use of plain air ducts and of wood as separators, I beg to disagree in part with Mr. McConnell in that I think an air duct of that kind is of more value than he realizes. It has been my experience the convection currents tend to go up and not across as the change of temperature tends to increase the air's buoyancy. I have made some tests which have shown it to be a very effective and efficient insulator, when in thicknesses of an inch or more. In elec-



Device for Testing Heat Conductivity of Insulation

trical work in getting rid of heat from a coil, it has been my experience in a number of instances, that a coil would get excessively hot if it had small air ducts through it.

A little device that I am employing at the present time in making some measurements of the characteristics of different kinds of electrical insulators as regards their heat insulating properties, is shown in the accompanying illustration.

In the bottom of a brass tube place a copper disc in the side of which is bored a hole of sufficient diameter to accommodate a thermometer. The outside of this tube is lined very thoroughly with asbestos to a depth of an inch or more.

It is open, with a small opening at the top and a tube passes down in there. A coil of wire serves as a heat coil. The entire inside is filled with mineral oil of high flash point, so as to permit operation at fairly high temperatures without any difficulty. Current is passed through the heat coil and the heat is produced in that way. At the same time the amount of heat that is put in is measured by the amount of energy electrically expended. The temperature can be determined by a thermometer placed in the opening A. The tests are conducted in this way: The material that is to be tested is placed as a sheet between discs A and B. Disc B is attached to a vessel which has circulating water in it and its temperature, which can be maintained quite constant, can be determined with a thermometer. Thus having the difference in temperature and amount of energy through the material, its conductivity can be calculated. The device, of course, is first standardized and a determination made of the radiation that takes place at various temperatures. This is done by placing the device on a large mat of hair or felt, so that the amount of heat lost in that way is a negligible factor, and noting the amounts of energy required to maintain various temperatures. A curve is platted between temperature and energy, or radiation as all the energy going in is radiated, and from it the corrections can be obtained for the radiation of the device when a test is being run on a sample of material of unknown value.

The apparatus is simple, effective, cheap, and easily operated and can doubtless be modified to be of service to refrigeration and steam engineers.

Arnold Stucki, Member—In regard to the apparatus described by Mr. Kintner, I notice there is no casing used to exclude the difference in temperature of the atmosphere and possible drafts, while the calorimeter used by Prof. Goss has such a casing inside of which the air was always heated to the same temperature in each test.

If I understood Mr. McConnell correctly he is under the impression that sheet iron was used in connection with the

insulating material to be tested. This, however, was not the case and the insulating material was the only intervening medium.

S. M. Kintner—Replying to Mr. Stucki's criticism; We have not found it necessary to introduce such refinements, probably for the reason that the percentage of energy that is radiated out through the wall, in comparison with the total amount involved, is so small that the error is not noticeable. The material that we have had under test is thin in comparison with the other material with which the device is insulated, and for that reason the percentage of error is not noticeable under average conditions.

Arnold Stucki—It has been claimed for linafelt that it is superior to other insulating materials in regard to deterioration by animal life. Worms would not get in it as they would in hair felt.

John A. McConnell—If you want to be sure of being free of vermin and animal life, by all means employ mineral wool or asbestos fibre. In mineral wool, which is simply a form of spun glass, animal life can not exist. As between flax and hair, probably hair would be a little more susceptible to animal life, but hair is the best non-conductor of heat that the world affords. Each individual hair is a tube and contains a strata of air on the inside, of even the finer forms of hair, known as fur, this is true, and while the author speaks of getting the particles too close together, yet that don't seem to be the fact because the finer particles of hair are better known insulators of heat than the coarser forms of hair. However, it is only under special conditions, in connection with kitchens of hotels for instance, that there is danger of animal life to any objectionable extent.

Samuel Diescher, Member—If a wall was built of several thicknesses of the best material, would it not be a better wall than one built of different materials, only one of which could be the best?

JOHN A. MCCONNELL—There is an advantage in using different kinds of materials, hair felt is an excellent non-conductor, but interposing a layer of paper prevents the passage of air which the hair felt does not.

A. STUCKI—I did not understand the paper to advocate the use of different kinds of insulating materials in one combination, on the contrary I see the author used only one kind at a time. When he spoke about materials of different density he had reference to intervening layers of paper and air.

JOHN A. MCCONNELL—In insulating pipe for refrigerating purposes, a common custom has been to place around the pipe a layer of tarred felt, and then place the insulator around that. My experience has proven that to be a mistake. Your workman carelessly wraps his layer of tarred felt around the pipe and in about five cases out of six does not get it tight and close to the pipe, and of course as soon as you get the air in contact with the cold pipe you produce water of condensation. My experience has shown that the insulator should always come in direct contact with the surface to be insulated.

*DETERMINATION OF CARBON IN STEEL BY DIRECT IGNITION WITH RED LEAD.

†CHARLES MORRIS JOHNSON.

Non-Member.

The writer's experience with this method for the determination of carbon, together with some notes on what led to its adoption for routine combustion analysis, may prove of interest.

The solution of steel drillings containing large percentages of chromium, tungsten or molybdenum in double chlorid of copper and potassium causes more or less loss of carbon as a gas. Especially sensitive to such loss are the carbids that are separated by the double chlorid from steels in which are present ten or twelve per cent of molybdenum, together with several percent of chromium.

These carbids may lose some of the carbon by contact with dilute acid, or with the oxygen of the air during washing with suction, or during the drying of the still moist carbid at the temperature of boiling water.

The carbid residue, separated from a steel containing 3.8% of chromium by the double chlorid of potassium and copper, was washed twenty times alternately with distilled water and a mixture of one part of concentrated hydrochloric acid and twenty parts of distilled water. This residue was then washed with water alone to remove the acid. After drying the carbid in a water oven, it was burned with oxygen in a red hot porcelain tube containing 5 inches of copper oxid.

The products of the combustion were passed through granulated zinc of 20 mesh fineness, then through calcium

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†Park Steel Company, Pittsburgh, Pa.

chlorid and then through phosphoric anhydrid. The purified CO_2 was absorbed and weighed in potash bulbs. A percentage of 1.65 of carbon was obtained. This steel was again treated as before, except that the carbid was washed with a mixture containing but 1 c. c. of concentrated hydrochloric acid in 100 c. c. of water. By this procedure 1.52% carbon was obtained, or .13% lower. A third analysis was made and the carbid was washed only two or three times with this very dilute acid, (1 part of acid to 100 parts of water) and then with water as before, when the much greater percentage of 1.909 was obtained. A duplicate of this last procedure gave 1.943% carbon.

As the odor of escaping hydrocarbon could be plainly detected with even but two washings of this extremely diluted hydrochloric acid, its use as a wash was entirely abandoned, water alone being used. From that time no difficulty was experienced in getting analyses to check within .01%.

In August 1902 this last described process was applied to a steel containing 4% of chromium and 4% of molybdenum. Four determinations were made of this steel with the following absence of agreement:

(1)	1.28%	carbon
(2)	1.53%	"
(3)	1.33%	"
(4)	1.29%	"

The thought then occurred that, perhaps, the carbid obtained from molybdenum steel gives up part of its carbon by being brought in contact with the air during stirring. (No heat was applied at any time.) Instead of stirring the drillings for the usual thirty minutes in the double chlorid solution, but twenty minutes stirring was resorted to and analysis (2) was confirmed 1.53% being found. This short period of stirring was tried a second time and 1.48% was the result. Encouraged by these closer agreements, the time of stirring was cut to 10 minutes and 1.64% carbon was recorded,

or .36% higher than (1). The drillings were then placed in double chlorid solution for 12 hours with no stirring and the residue was filtered, washed, dried and burned as usual. This procedure yielded 1.49%. Twenty-four hours contact with the double chlorid and no stirring was tried with the result of 1.52% carbon.

The double chlorid solution in the foregoing experiments was quite acid, consisting of 600 grammes of the double chlorid of copper and potassium, 1500 c. c. distilled water and 175 c. c. concentrated hydrochloric acid.

A nearly neutral solution of the double chlorid was prepared, consisting of 600 grammes of double chlorid, 1500 c. c. of water and 25 c. c. of concentrated hydrochloric acid. Two grammes of this steel were dissolved in 180 c. c. of the solution with 8 minutes stirring. Two determinations by this method yielded 1.60 and 1.55% carbon. At this juncture two grammes of the drillings were dissolved in 180 c. c. of the strongly acid chlorid with three minutes stirring and the usual rapid washing with water only, and 1.60% carbon was obtained. This was further evidence that for this class of carbids considerable acidity in the double chlorid solution is not the principal cause of low results. Further, an entirely neutral solution was tried consisting of 600 grammes of the double chlorid of copper and potassium, and 1500 c. c. of distilled water with no acid added. Two grammes of steel stirred six minutes in 180 c. c. of this solution yielded (1) 1.593, (2) 1.606%, or not quite as high as the maximum result obtained with the acid chlorid process.

Another steel of approximately the same composition was experimented with along the same lines, the supply of drillings from the first molybdenum-chromium steel having been exhausted. The outline of this work is as follows:

Two grammes of No. 2 steel, neutral solution, 4 min. stirring, ... 1.679%

Two grammes of No. 2 steel, neutral solution, 6 min. stirring, ... 1.734%

Two grammes of No. 2 steel, acid solution, 4 min. stirring, ... 1.758%

Two grammes of No. 2 steel, acid solution, 4 min. stirring, ... 1.66 %

A combustion by the red lead process, hereinafter to be described, yielded a percentage of 1.734 carbon from the No. 2 drillings.

Short stirring and rapid washing had evidently not eliminated all of the causes of loss as shown by the above results which differ by as much as 0.09%. Perhaps there is a loss of carbon when the carbid is being dried at the temperature of the water oven. Further, it is practically impossible to regulate the suction so as to expose the residues during the washing to exactly the same amounts of air.

The following three analyses shed some light on the effect of drawing air through the carbid residue during the washing, or in other words, the effect of exposing the moist residue to large volumes of air: Two grammes of No. 2 Mo-Cr steel were stirred 20 minutes with 180 c. c. of the acid double chlorid solution, then transferred to the asbestos plug and air was drawn through the residue for 50 minutes. The percentage obtained was 1.347%, or 0.41% lower than the maximum. Two determinations of this steel were then made with 60 minutes stirring in each case, but with the least possible exposure to suction, and gave 1.63% and 1.68%, or practically the same result as was obtained previously with 180 c. c. of double chlorid, two grammes sample and a four minutes stirring. Returning to this sample several months later, two tests were made with 180 c. c. acid double chlorid, 30 minutes stirring and the least possible exposure to air by suction; 1.699% and 1.697% carbon obtained.

In view of these results the practice was adopted of always keeping a layer of distilled water over the carbid residue during the washing, that is, as soon as one layer of water was drawn off by the suction another layer of water was immediately supplied.

The next group of alloy steels examined contained considerably more molybdenum, namely 11.%, also some chromium. In this class the neutral copper chlorid and potassium solution gave more concordant results. Short stirring and least possible exposure to air during suction and wash-

ing was observed with both the acid double chlorid and the neutral double chlorid processes. The solution of the drillings in the acid double chlorid gave (1) 0.52, (2) 0.46, (3) 0.53% carbon. The solution of the drillings in the neutral double chlorid yielded (1) 0.60, (2) 0.56, (3) 0.59%, or an average of 0.503% by the acid process and an average of 0.583% by the neutral solution.

The climax of disagreement was reached in April, 1904, when the writer was called upon to report the percentage of carbon in a group of ingots containing 11 to 12% of molybdenum together with several per cent of chromium. Using neutral double chlorid solution, least possible exposure to air during suction and short stirring the following discordant results were obtained:

	Neutral copper and potassium chlorid:	Red lead process:
Ingot No. 1	.54% carbon.	.80% carbon
	.72 "	.79 "
Ingot No. 2	.81 "	
	.51 "	.76 "
Ingot No. 3	.66 "	
	.49 "	.82 "
	.51 "	
Ingot No. 4	.54 "	
	.58 "	.81 "
Ingot No. 2 "(trial)"	.47 "	.88 "
	.61 "	.85 "
Ingot No. 5	.61 "	.88 "
	.88 "	.87 "

Ingot No. 6	.49% carbon.	.73% carbon.
Sample S. H. S.	.88 "	
	.75 "	
	.69 "	
	.66 "	
	.68 "	
Other well known crucible steel laboratories reported on sample S. H. S.	.72 "	
	.64 "	
Neutral double chlorid:		Red lead process:
No. 7	.66% carbon.	.94% carbon
	.52 "	.939 "
No. 10	.76 "	
	.75 "	1.00 "
	.62 "	
No. 11	.72 "	
	.52 "	.80 "

(The results obtained from this series by the red lead process are inserted above for convenient comparison.)

It may be of interest to mention that all of the Mo. steels, even those in which the molybdenum was as low as 2% gave off an odor slightly suggesting carbon disulphid. This odor was noticeable, of course, during the stirring of the drillings with either neutral or acid double chlorid solution. All steels whether dissolved in the acid or the neutral double chlorid,

yield more or less of an odor suggesting hydrocarbons, but that coming from the molybdenum steels is much more marked and of a type peculiar, in the writer's experience at least, to steels containing molybdenum.

This utter untrustworthiness of the double chlorid process for the determination of carbon in steels of high molybdenum content, led to a search for some method of obtaining the carbon by burning the entire substance. Having about this time noted Brearly and Ibbotson's statement that steel drillings that will pass a twenty mesh sieve, and have previously been mixed with about three times their weight of red oxide of lead, can be decarbonized in about twenty minutes in a red hot porcelain tube, it was decided to attack the molybdenum steel in this manner.

The method was first applied to plain carbon steels of known carbon content. The siftings and the red lead were shaken together in a glass stoppered weighing bottle and then transferred to a porcelain boat. The charge was pressed firmly together with a pair of forceps and a thin layer of asbestos covered the exposed portion of the charge to prevent creeping. The boat was slipped into a ¾ inch inside diameter porcelain combustion tube, twenty-four inches long, and containing about 5 inches of copper oxid. The stream of oxygen passed through a pre-heating furnace containing red hot copper oxide, then through a jar containing pieces of solid caustic potash about the size of a peanut kernel. It next bubbled through liquid caustic potash and was dried in jars of soda-lime and calcium chlorid. This drying and purifying apparatus can be easily arranged and securely fastened in a space of 10 by 16 inches.

The combustions were conducted in the usual manner, the portion of the tube containing the copper oxid was first heated to bright red and then the remainder of the tube lying within the furnace was brought to the same temperature. As soon as the steel began to oxidize, the oxygen, being absorbed, ceased to pass through the potash bulbs. More oxygen was then supplied In from ten to twenty-five min-

utes, depending on the weight of the charge, after the stoppage, the oxygen ceased to be absorbed and began to pass through the absorption apparatus at a high rate of speed, indicating that the combustion was practically complete.

The speed of the oxygen was then checked. In the majority of these determinations, fifteen minutes further heating, with oxygen passing through the furnace, was resorted to as an extra precaution. The products of the combustion were dried and purified by passage through a tower of metallic zinc, a U-tube of anhydrous calcium chlorid and a second tower of phosphoric anhydrid. The carbon dioxid was absorbed in potash bulbs and weighed.

The following are some comparative results:

Plain carbon steel, S. S. Co., by acid double chlorid gave, ... .415% C.
By the red lead (9 grammes lead oxid and three grammes of steel) ..... .395% C.

No. 690 average of many combustions by acid double chlorid gave, ... .985% C.
No. 690 by red lead, ... .96 % C.

No. 350 (A steel containing ½% tungsten gave by double chlorid) ..... 1.29 % C.
No. 350 by red lead, ... 1.285% C.

No. 353 (A steel similar to No. 350) gave by double chlorid, ... 1.354% C.
No. 353 by red lead, ... 1.338% C.

Steel No. 22 (high per cent nickel steel) by double chlorid, ... .696% C.
Steel No. 22 by red lead, ... .698% C.

Steel No. 14 (similar to No. 22) gave by double chlorid.. .450% C.
Steel No. 14 by red lead, ... .447% C.

Steel S x 1 x—215 (a 5.6% tungsten steel), by double chlorid ..... 2.35 % C.
by red lead, ... { 2.40 % C. / 2.39 % C.

Wash metal (1½ grammes of sample plus 1½ grammes red lead) ..... 3.56 % C.
Wash metal (1½ grammes of sample plus 1½ grammes red lead) ..... 3.65 % C.
Wash metal (1½ grammes of sample plus 3 grammes of red lead) ..... 3.58 % C.
Wash metal by acid copper chlorid, ... 3.59 % C.

C. B. Pig metal by the double chlorid process gave, ... 4.04 % C.
C. B. Pig metal (1½ grammes sample plus ¾ grammes red lead) ..... 4.01 % C.
C. B. Pig metal (1½ grammes sample plus 1½ grammes red lead) ..... 4.04 % C.
C. B. Pig metal (3 grammes sample plus 3 grammes red lead) ..... 4.04 % C.

In July, 1902, a sample of steel was sent to various laboratories for check analyses:

Atha Steel works reported carbon, ... 1.25 %
Crescent Steel works reported carbon, ... 1.20 %
Park Steel works reported carbon, ... 1.214%
Spaulding Jennings reported carbon, ... 1.199%
Sanderson Bros. reported carbon, ... 1.214%
La Belle Steel works, reported carbon, ... 1.20 %

All the above laboratories, in all probability, used some form of the double chlorid process as did the writer at that time. Still having a considerable portion of the drillings, three grammes of it were burned with 1½ grammes of red lead and the percentage of 1.22 was obtained. The writer also had in his collection a sample of plain carbon steel, sent out in March, 1901, by Sanderson Brothers.

Booth, Garret & Blair found carbon 1.277%
Sanderson Brothers, found carbon 1.292%
Park Steel Co., found carbon 1.301%
Bethlehem Steel Works found carbon 1.307%
Crescent Steel Co., found carbon 1.315%

Three grammes of these drillings were decarbonized with 1½ grammes of red lead and 1.305% carbon was obtained.

A low carbon steel yielding .185% carbon by the double chloride separation was tested by burning six grammes of it with three grammes of red lead and .192% was the result.

Eight grammes of a steel showing .077% carbon by the double chlorid process was burned with four grammes of red lead and .097% carbon was found.

FERRO ALLOYS:

Those samples of ferro-tungsten with which the writer has had to deal have yielded their carbon on ignition with red lead with ease. The ferro-chromiums have proven more refractory. Ferro-chromium of about 65% chromium was ignited with varying quantities of red lead. Sample ("A"):

1 gramme of the alloy on being burned with 2 grammes red lead yielded ..... 7.26 % C.
1 gramme of the alloy on being burned with 3 grammes red lead yielded ..... 7.54 % C.
1 gramme of the alloy on being burned with 4 grammes red lead yielded ..... 7.72 % C.
½ gramme of the alloy on being burned with 3 grammes red lead yielded ..... 7.73 % C.
7.73% evidently being the maximum.

Ferro—chrome (B):
½ gramme of sample burned with 2½ grammes of red lead gave ..... 7.03 % C.
gramme of sample burned with 4 grammes of red lead gave ..... 7.00 % C.

Ferro—chrome (C):
½ gramme of sample burned with 2½ grammes of red lead gave ..... 6.46 % C.
½ gramme of sample burned with 3½ grammes of red lead gave ..... 6.55 % C.

These samples of ferro-chromium seem to require three or four times their weight of the minium.

Ferro—chrome (D):
1 gramme of sample burned with 1 gramme of red lead gave ..... 6.05 % C.
1½ grammes of sample burned with ¾ gramme of red lead gave only ..... 5.17 % C.

1 gramme of sample burned with 2 grammes of red lead gave ..... 6.403% C.
1 gramme of sample burned with 4 grammes of red lead gave ..... 7.094% C.
1 gramme of sample burned with 3 grammes of red lead gave ..... 7.15 % C.

Ferro—chrome (E):

1 gramme of sample burned with 4 grammes of red lead yielded ..... 7.07 % C.
½ gramme of sample burned with 4 grammes of red lead yielded ..... 7.18 % C.

During more than eighteen months daily use of the red lead process certain changes in the method, as originally practiced, have been made.

The ordinary ten burner Bunsen furnace is used but with certain alterations to secure higher heating power. At the points where the porcelain tube rests in the ends of the furnace, these ends were slotted down about one inch. This permits the tube to lie in the hotter part of the furnace and be well enveloped with the flame. Further, under each foot of the furnace a piece of fire brick 1⅛ inches thick was placed. Also the row of burners was lowered until it rests on the table on which the furnace stands. To keep the row of burners vertical, one burner at each end of the row was wired to the furnace. This lowering of the burners and raising of the furnace frame greatly improves the draught and secures a hot furnace when natural gas is used.

Fig 3 shows the tower, or jar, that is used as a container for the pieces of K O H for purifying the oxygen as it leaves the preheating furnace. This jar serves the same purpose for the 20 mesh zinc and the phosphoric anhydrid. The writer designed this jar several years ago to hold solid driers and purifiers, avoiding the use of rubber stoppers. The glass neck A is joined to the cylinder B by a piece of heavy combustion tubing. The cylinder is one inch in diameter by 10 inches high. It is refilled by removing the goose neck at A.

Fig 1 was designed to hold the liquid K O H through which the oxygen also bubbles as it leaves the preheating furnace. It serves to show the speed at which the gas is leaving the furnace and also as a purifier. The oxygen enters the chamber E and bubbles through the chamber F, which is filled about one-third full with liquid K O H. The

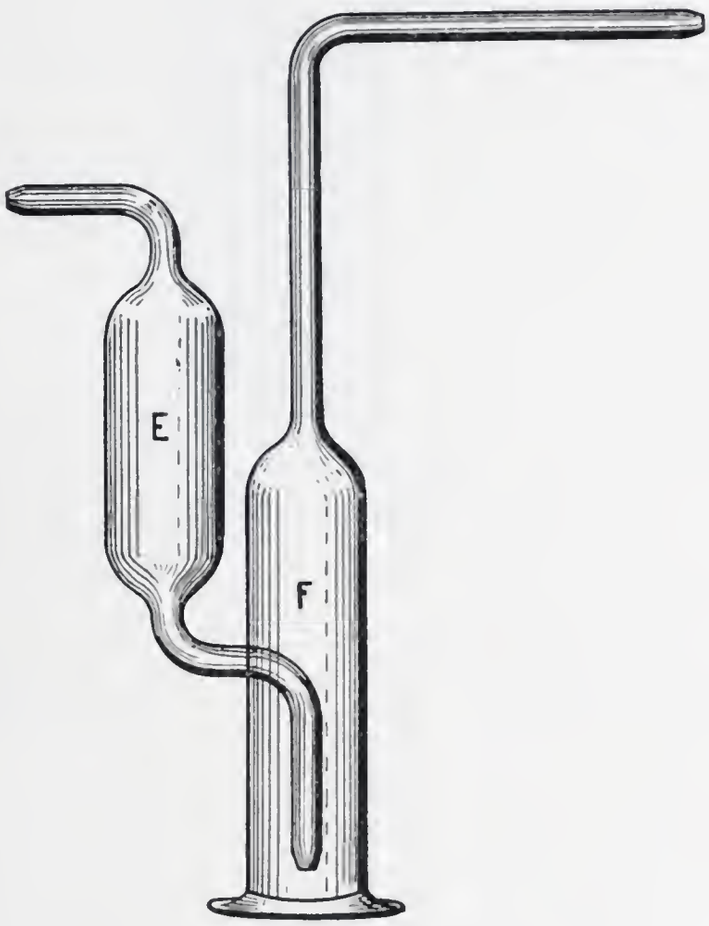

FIG.

chamber E. is intended to prevent the liquid from blowing over into the rubber tubing or other parts of the apparatus. This it does very effectively.

Fig. 2 was designed as a substitute for the ordinary forms of potash bulbs for the weighing of the carbon dioxid obtained in carbon combustions. The CO_2 enters the bulb A and bubbles through the liquid K O H held in B. The tube C is the drying tube, which the author prefers to fill with small pieces of dry K O H obtained by quickly cracking the sticks in a porcelain mortar. This apparatus after

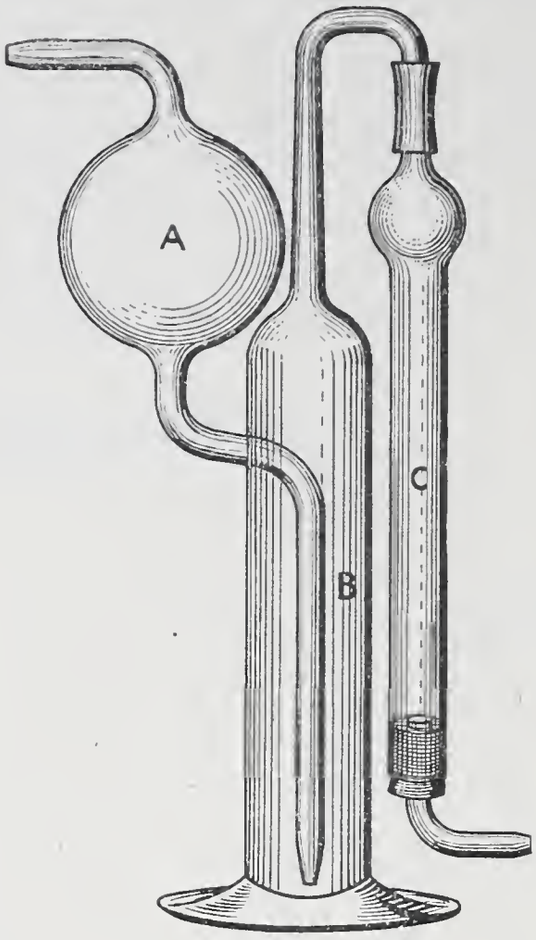

FIG. 2.

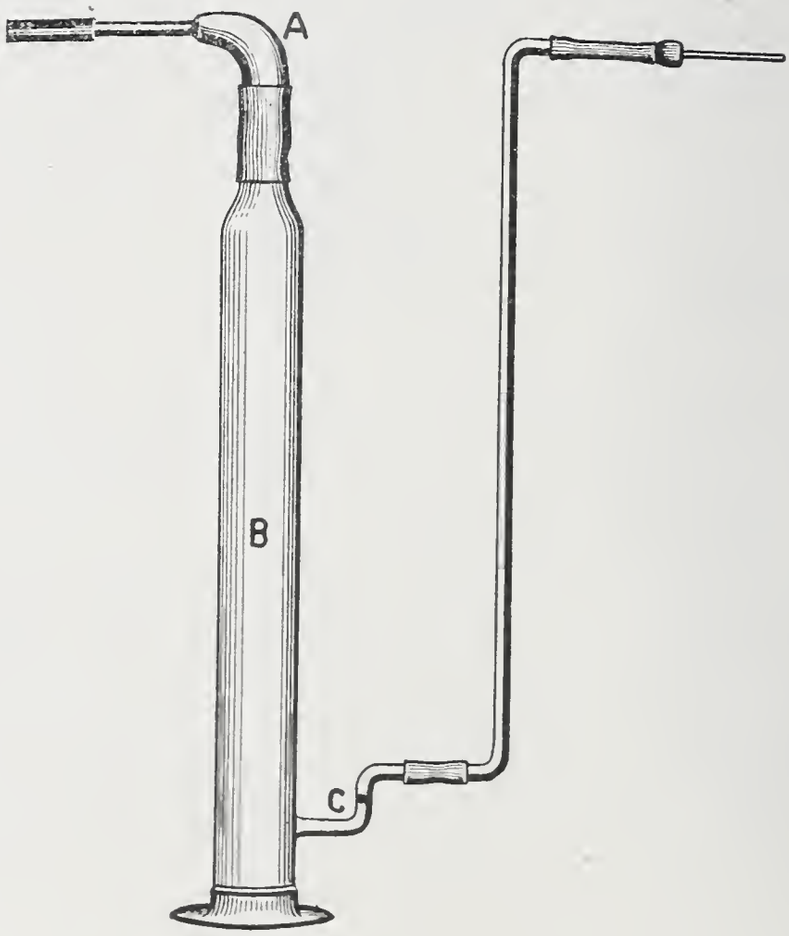

FIG. 3.

thorough testing proved quite as efficient as the Geissler form, does not occupy so much space in the balance case and is not top-heavy.

Fig. 2 is about ½ actual size of the apparatus.

The present practice is to absorb the CO_2 in $Ba(O-H)_2$ solution. The $BaCO_3$ is ignited and weighed. For percentages exceeding .50% carbon, 1½ to 2 grammes of the steel are weighed with 4 grammes of the Pb_3O_4. For lower percentages 2½ to 3 grammes of the drillings are weighed with 4 grammes of the lead oxide. The ideal sample for the combustion is that portion which passes the 20 mesh gauze of a double sieve but will be found on the 30 mesh gauze. This process removes the bulkier and thicker borings and also the fine dust. While such a selection is desirable, it is by no means necessary. It very rarely happens in unannealed steel that plenty of thin curly drillings cannot be obtained. These drillings, though far bulkier than the 20 mesh size, are readily decarbonized, but care must be exercised to have such steel in contact with the red lead, or portions of it will escape complete oxidation. After each combustion the boat and its contents should be examined. The cinder should be either well melted down or else swelled up, being easily reduced to the finest powder and of an almost jet black to brownish black color. Drillings that are coated with red oxid of iron have practically escaped decarbonization from not having been surrounded by the minium.

For drilling samples that are of lower carbon ranging from 0.04% to 0.30%, flat bitted drills should be used such as any mill blacksmith can make by hand. Such drills grind much of the drillings from either low carbon steels, or high carbon *annealed* steels to a sufficiently fine state to pass the twenty mesh gauze.

Drillings of ⅓ mm. thickness should decarbonize readily, but they must be well covered with the red lead. On one occasion it was necessary to analyze a sample of turnings that were 1 mm. thick. The decarbonizing was so nearly complete that the result checked within .02% of that obtained

by acid potassium and copper chlorid determination. The percentage of carbon in this instance was .35%.

The drillings are transferred to the weighing bottle as described; well shaken and then poured into a porcelain boat 112 mm. long by 12 mm. wide and 19 mm. deep. The charge is well pressed down and part of the lead oxid is spread over the top. A thin layer of ignited asbestos firmly pressed over the charge prevents, to a considerable extent, the creeping of litharge that forms during the ignition. Two complete sets of combustion furnaces with their accompanying trains are operated together, so that the combustions can be made in pairs.

The boats are pushed into the porcelain tubes until the asbestos plug that holds the copper oxid in place is reached. The copper oxid is kept red hot at all times, five burners being in use. This saves time and lengthens the life of the tubes. Clay gutters support the tubes and prevent too rapid cooling. Where the rubber stoppers are inserted in the tubes, strips of wet blotting paper are wrapped around the ends of the tubes to keep the stoppers from burning. These strips dip into suitable vessels of water. It was found that porcelain tubes would often break when plugs of oxidized copper gauze were used at the plug, owing to unequal coaling, hence the asbestos plugs. The oxygen passes through the apparatus containing the liquid K O H, (Fig 1) after leaving the preheater, at the rate of about 38 beats per ten seconds. The tubes are now tightly stoppered and the remaining five burners are lighted.

The stream of oxygen is regulated by screw-cocks to pass each set of the $Ba(OH)_2$ tubes at the same rate of speed. The charge begins to burn in 3 to 5 minutes, as shown by the oxygen almost or entirely ceasing to bubble through the $Ba(OH)_2$ tubes. The speed of the oxygen as it bubbles through the liquid K O H (Fig. 1) is now increased so that a very slow bubbling is maintained in each set of $Ba(OH)_2$ tubes. In about ten to fifteen minutes the burning is over and the gas begins to rush through the $Ba(OH)_2$ tubes.

The speed of the gas in the liquid K O H is now checked to the normal of 38 bubbles per 10 seconds. From this stage the burning is continued for 20 minutes more to insure complete oxidation, and that all of the CO_2 has been carried over into the the $Ba(OH)_2$ solution. The products of the combustion pass through a jar filled with 20 mesh zinc immediately after leaving the porcelain tubes.

The $Ba(OH)_2$ absorption apparatus consists of two 10 inch by 1 inch test tubes connected in tandem, each holding 70 c. c. of the solution with some space to spare. The first tube catches practically all of the CO_2 but a little from the higher carbon steels escapes into the second tube.

These tubes are of heavy glass, are provided with 30 c. c. marks and are filled with distilled water to this point. The $Ba(OH)_2$ solution is then poured into the 70 c. c. marks. The $Ba(OH)_2$ solution is made by dissolving, or nearly dissolving, 200 grammes of the hydrate in four litres of water. It is filtered through a pulp filter and preserved with the usual precautions.

The $Ba\ Co_3$ precipitates obtained from the combustions are filtered through 12 cm. filters reinforced at the apex with a piece of cheesecloth about ¾ of an inch square. The precipitates are washed 30 times with distilled water, allowing each washing to be drawn off by slight suction.

The cheesecloth is removed and the precipitates are ignited and weighed. From this weight the amount of $Ba\ CO_3$ formed from the CO_2 in the lead oxid, and that obtained from the unavoidable exposure of the excess of the hydrate during the filtrations, is deducted. From this net weight the percentage is calculated. The porcelain boats are cleaned for further use by standing them in 1.20 sp. gr. nitric acid for several hours. Hydrochloric acid should not be used as it causes the boats, after they have been used once or twice, to crack and fall apart as though they had been dropped on a hard surface. Frequently the entire cinder can be scraped out with the end of a file. The porcelain tubes of 14-16 mm.

inside diameter, glazed inside and outside, in the writer's experience, give the longest service.

The red lead should be thoroughly ground and mixed before the blank is determined. It should be as carefully mixed as a sample of ore that is being prepared for careful analysis. The ordinary so-called "pure" lead, costing about 9c per pound in 50 pound lots, is very satisfactory after being well mixed. It should be kept in a glass stoppered bottle. The lead should not contain small lumps of unconverted carbonate.

Combustions can be made accurately in 75 minutes time, counting *all manipulations* and calculations from the time the drillings are placed in the operator's hands until the result is on the report sheet. By using some form of alkali and acid titration, it is hoped to cut this time to 55 minutes. Experiments along this line are now being made.

One quarter to one half gramme of MgO should be packed firmly in the bottom of the porcelain boat before adding the mixture of red lead and drillings. This precaution prolongs the life of the boat to 6 or 7 combustions. The style of boat already mentioned was quoted last month at $28.80 per gross. The cost per combustion due to wear of boats should not exceed 3 ⅓ cents. The porcelain combustion tubes last 3 to 4 weeks, in this laboratory, being in service night and day. The use of MgO increases the blank.

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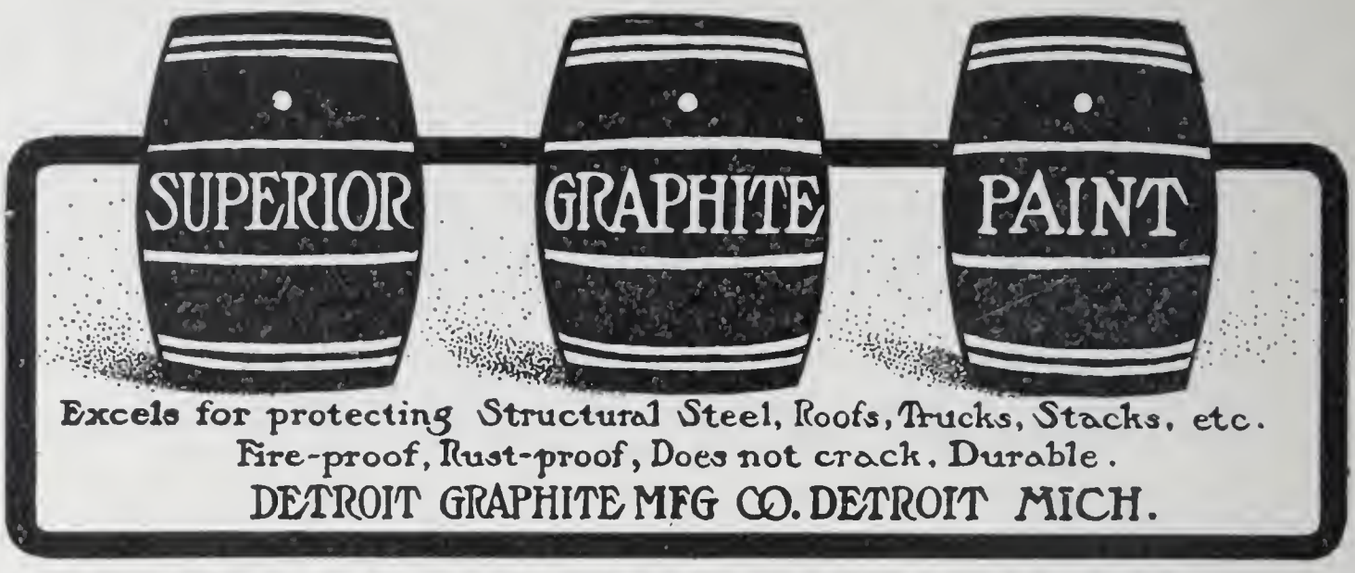

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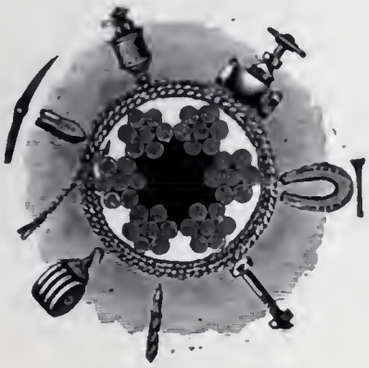

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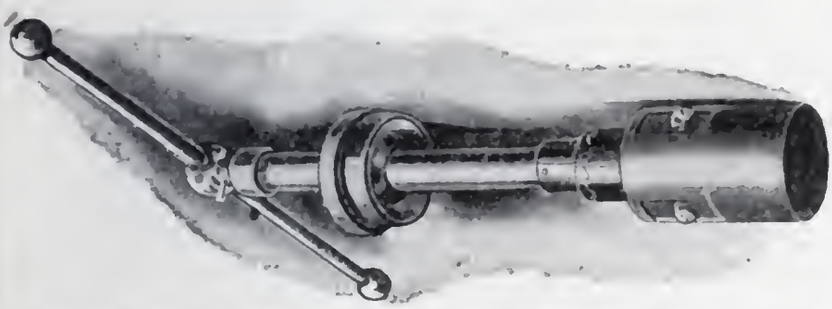

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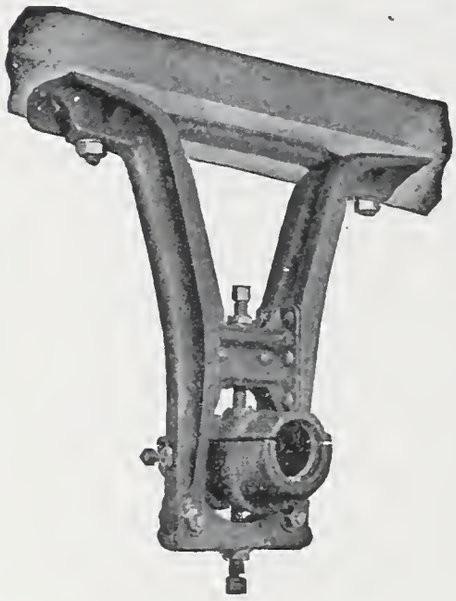

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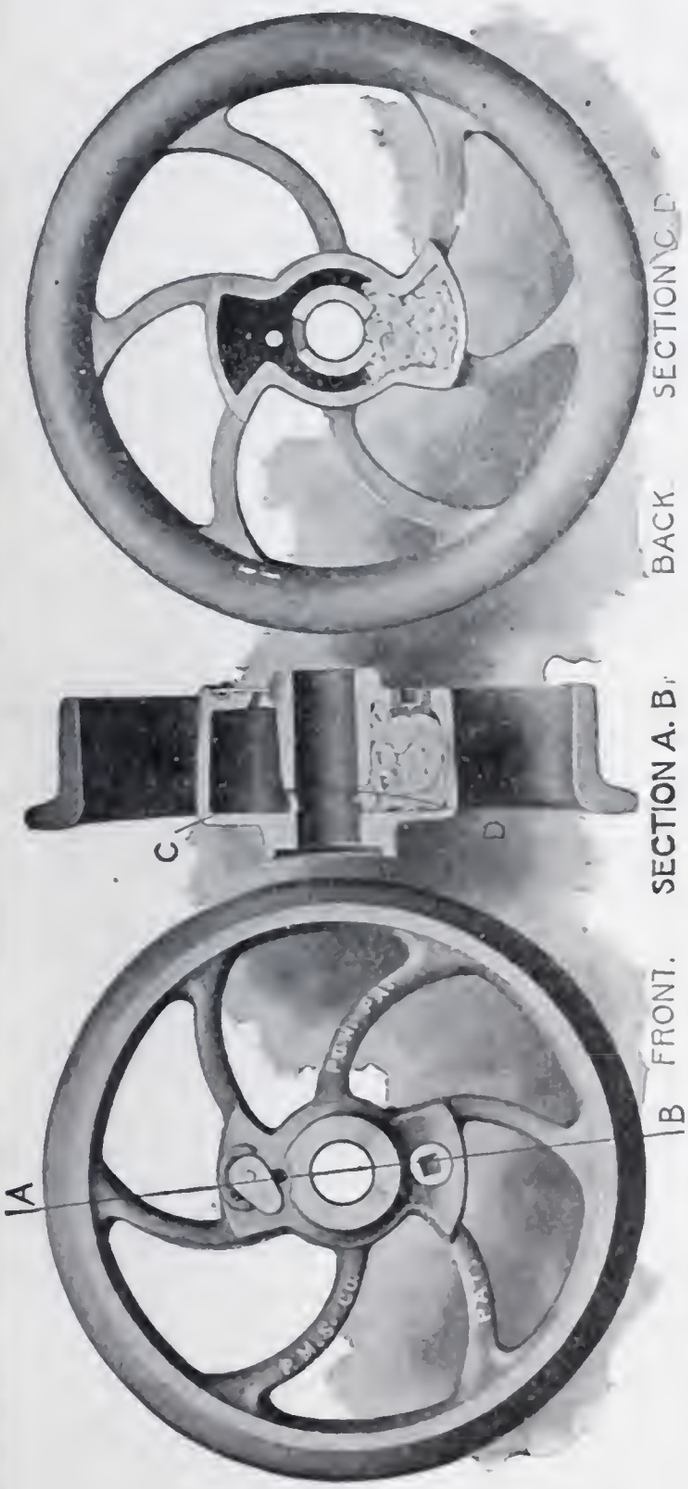

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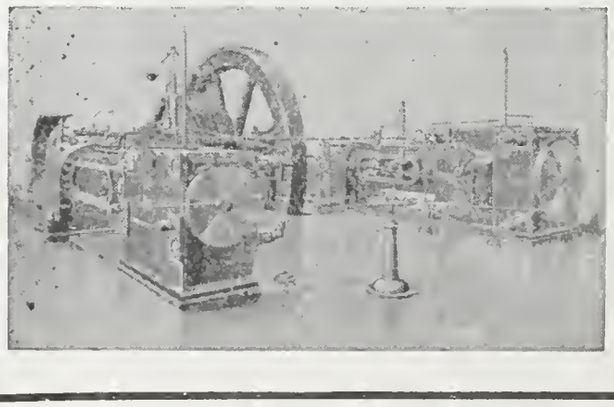

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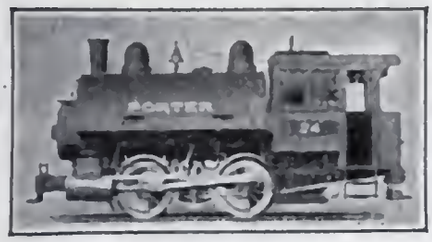

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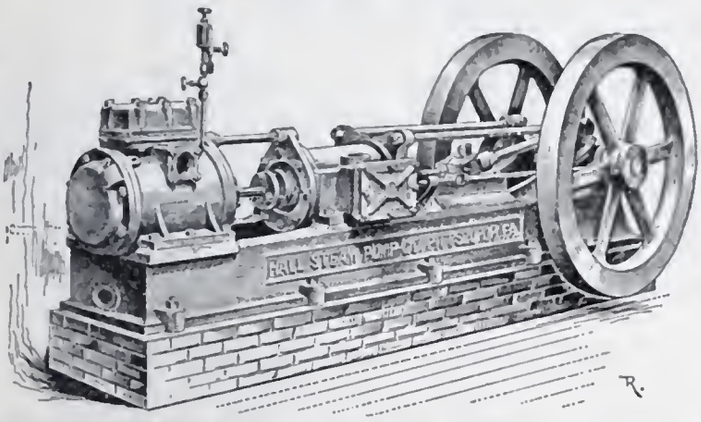

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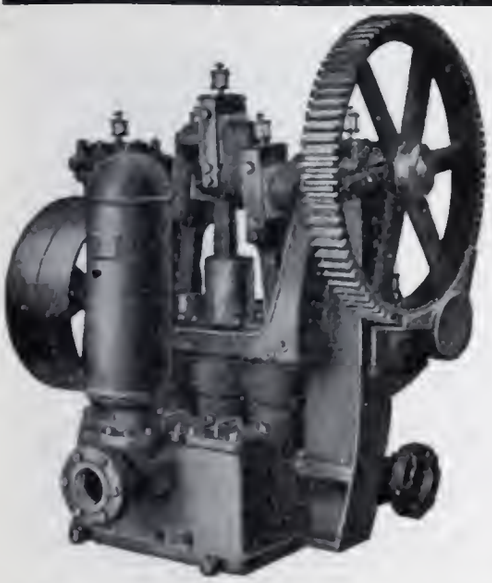

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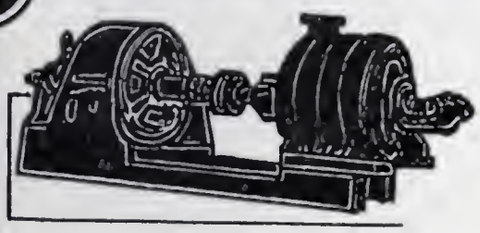

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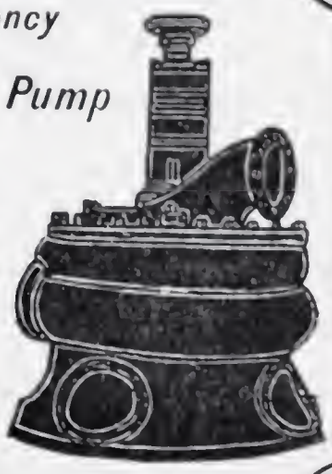

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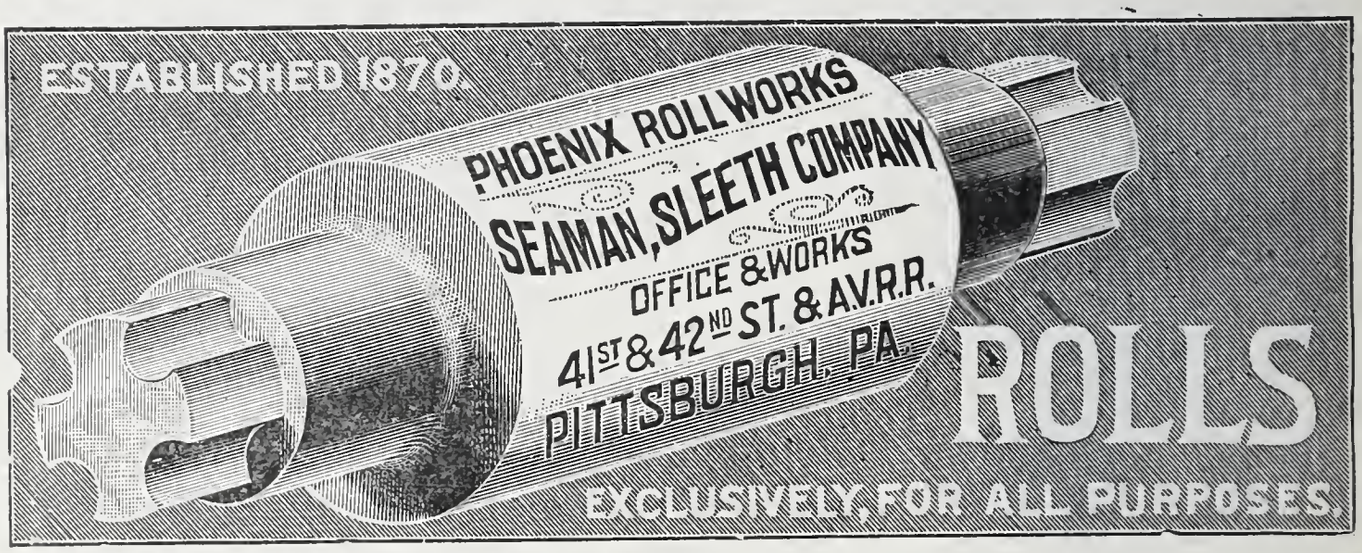

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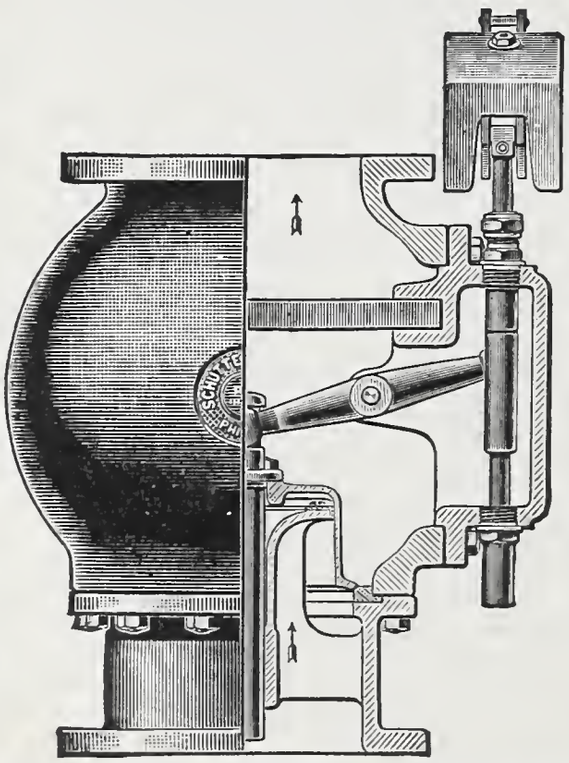

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Diescher, S. & Sons
Donley, Wm. McC.
Duckham, A. E.
Schellenberg, F. Z.
Smith, R. L.
Kennedy, Julian
Swensson, Emil
McGrew, J. & E.

Engineers—Mechanical.
Ashworth, D.
McMullin, F. V.
S. Diescher & Son.
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Kennedy, Julian
S. V. Huber & Co.
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